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(12) **United States Patent**
Takakura

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(45) **Date of Patent: Oct. 25, 2016**

(54) **INFORMATION PROCESSING DEVICE, INFORMATION PROCESSING SYSTEM, STORAGE MEDIUM STORING PROGRAM FOR CONTROLLING INFORMATION PROCESSING DEVICE, AND METHOD FOR CONTROLLING INFORMATION PROCESSING DEVICE**

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(30) **Foreign Application Priority Data**

Mar. 31, 2014 (JP) 2014-072265

(51) **Int. Cl.**

G06F 12/00	(2006.01)
G06F 13/16	(2006.01)
G06F 12/10	(2016.01)
G06F 3/06	(2006.01)

(52) **U.S. Cl.**

CPC ***G06F 13/1642*** (2013.01); ***G06F 3/061*** (2013.01); ***G06F 3/0659*** (2013.01); ***G06F 3/0676*** (2013.01); ***G06F 12/1018*** (2013.01); *G06F 3/067* (2013.01); *G06F 2212/657* (2013.01)

(58) **Field of Classification Search**

CPC .. G06F 13/1642; G06F 3/061; G06F 3/0659; G06F 3/067; G06F 3/0676; G06F 12/1018; G06F 2212/657

See application file for complete search history.

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(57) **ABSTRACT**

An information processing device, comprising: a memory; and one or more central processing units coupled to the memory and configured to: control accesses to a device based on requests from users, record a start time of each access to the device and an end time of the access to the device, determine a load state of the device based on an elapsed time period from the start time to the end time, and limit, based on the load state of the device, a number of threads for one of the users, the threads being concurrently executed to access the device based on access requests to the device from the one of the users.

9 Claims, 19 Drawing Sheets

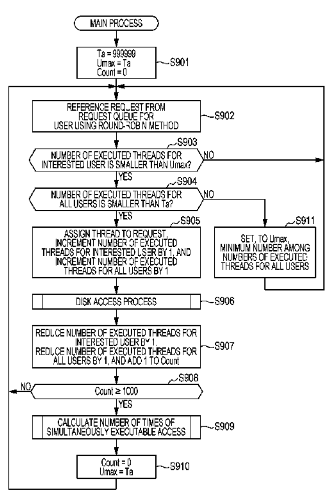
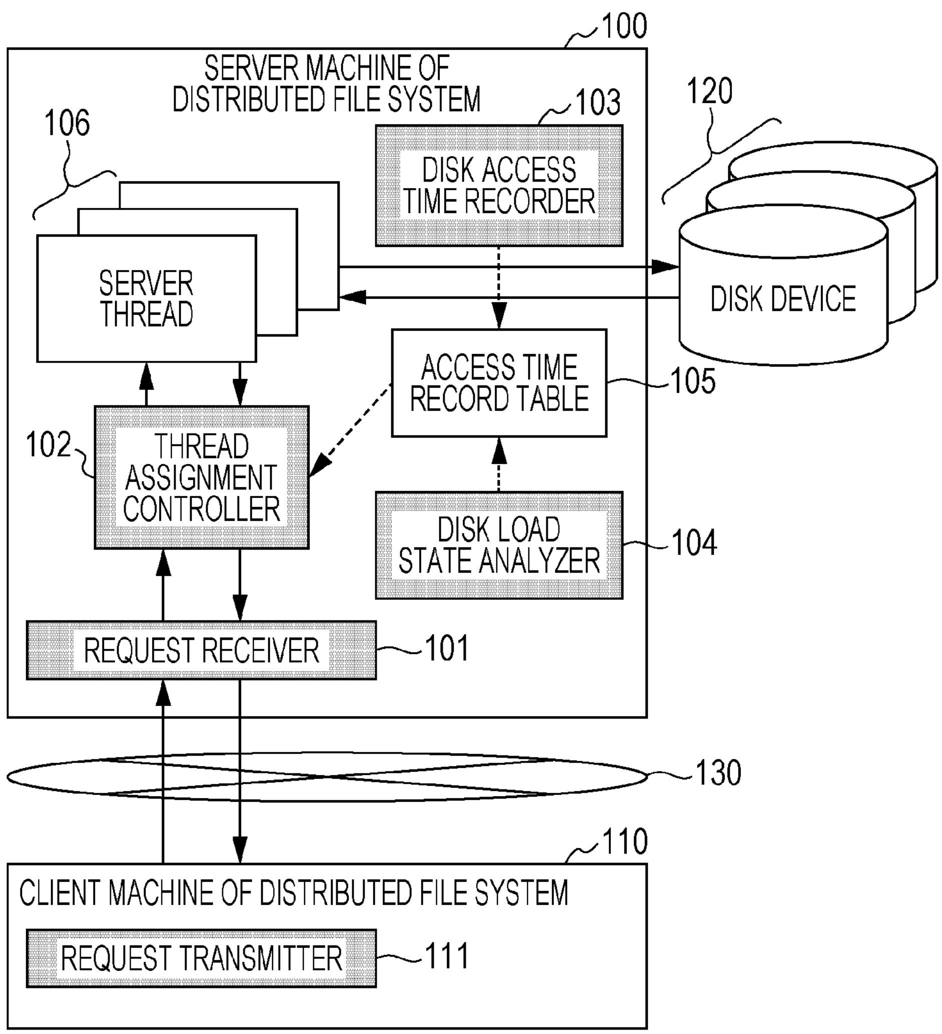


FIG. 1

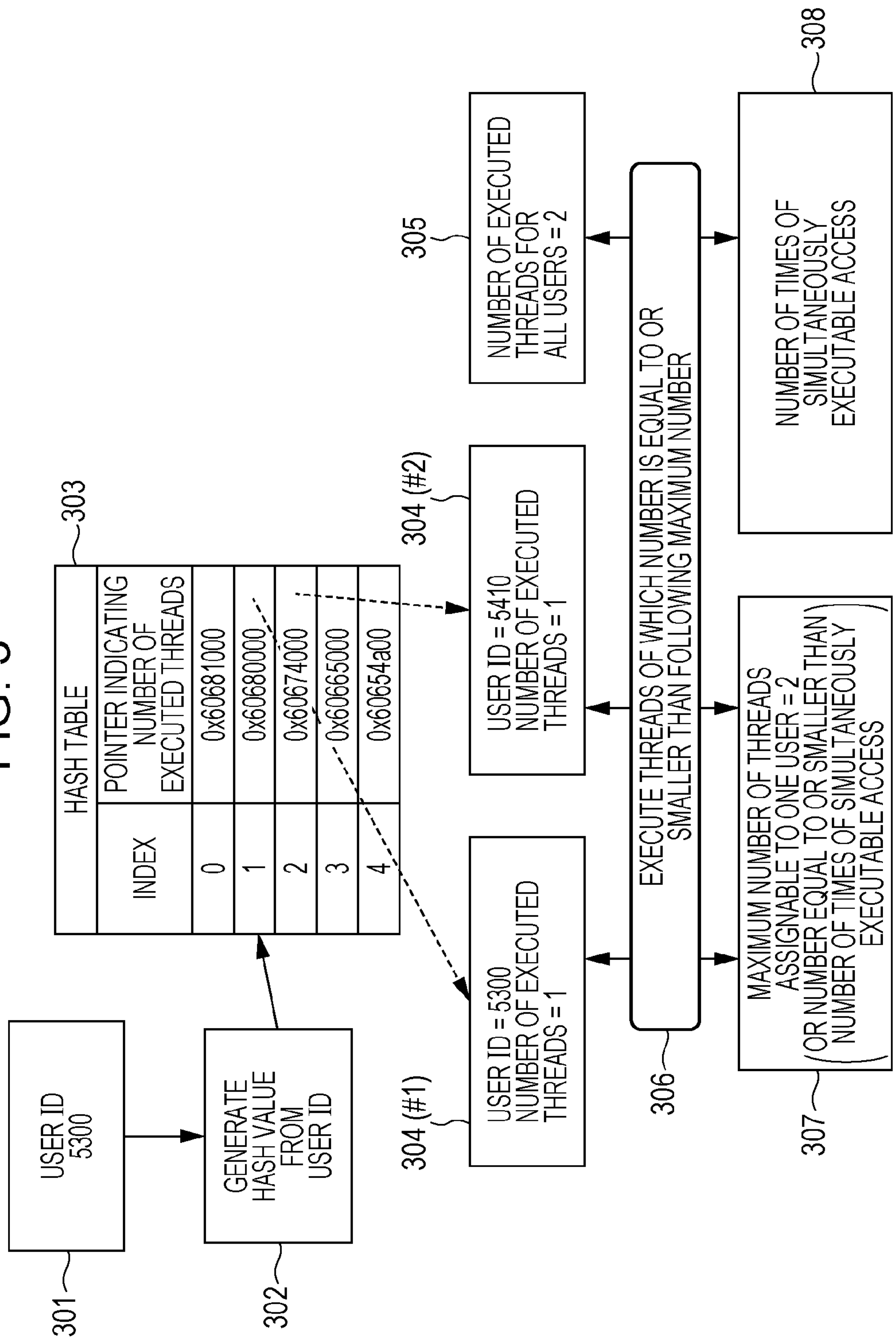


100
SERVER MACHINE OF DISTRIBUTED FILE SYSTEM
106
SERVER THREAD
103
DISK ACCESS TIME RECORDER
120
DISK DEVICE
ACCESS TIME RECORD TABLE
105
102
THREAD ASSIGNMENT CONTROLLER
DISK LOAD STATE ANALYZER
104
REQUEST RECEIVER
101
130
110
CLIENT MACHINE OF DISTRIBUTED FILE SYSTEM
REQUEST TRANSMITTER
111

FIG. 2

	ELAPSED TIME PERIOD (MILLISECONDS)														
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
FILE ACCESS 1															
FILE ACCESS 2															
FILE ACCESS 3															
FILE ACCESS 4										WAIT					
FILE ACCESS 5											WAIT	WAIT			
FILE ACCESS 6									WAIT		WAIT				
FILE ACCESS 7										WAIT		WAIT	WAIT		
FILE ACCESS 8											WAIT		WAIT		

FIG. 3



301
USER ID 5300
302
GENERATE HASH VALUE FROM USER ID
303
HASH TABLE
INDEX
POINTER INDICATING NUMBER OF EXECUTED THREADS
0
0x60681000
1
0x60680000
2
0x60674000
3
0x60665000
4
0x60654a00
304 (#1)
USER ID = 5300 NUMBER OF EXECUTED THREADS = 1
304 (#2)
USER ID = 5410 NUMBER OF EXECUTED THREADS = 1
305
NUMBER OF EXECUTED THREADS FOR ALL USERS = 2
306
EXECUTE THREADS OF WHICH NUMBER IS EQUAL TO OR SMALLER THAN FOLLOWING MAXIMUM NUMBER
307
MAXIMUM NUMBER OF THREADS ASSIGNABLE TO ONE USER = 2 (OR NUMBER EQUAL TO OR SMALLER THAN NUMBER OF TIMES OF SIMULTANEOUSLY EXECUTABLE ACCESS)
308
NUMBER OF TIMES OF SIMULTANEOUSLY EXECUTABLE ACCESS

FIG. 4

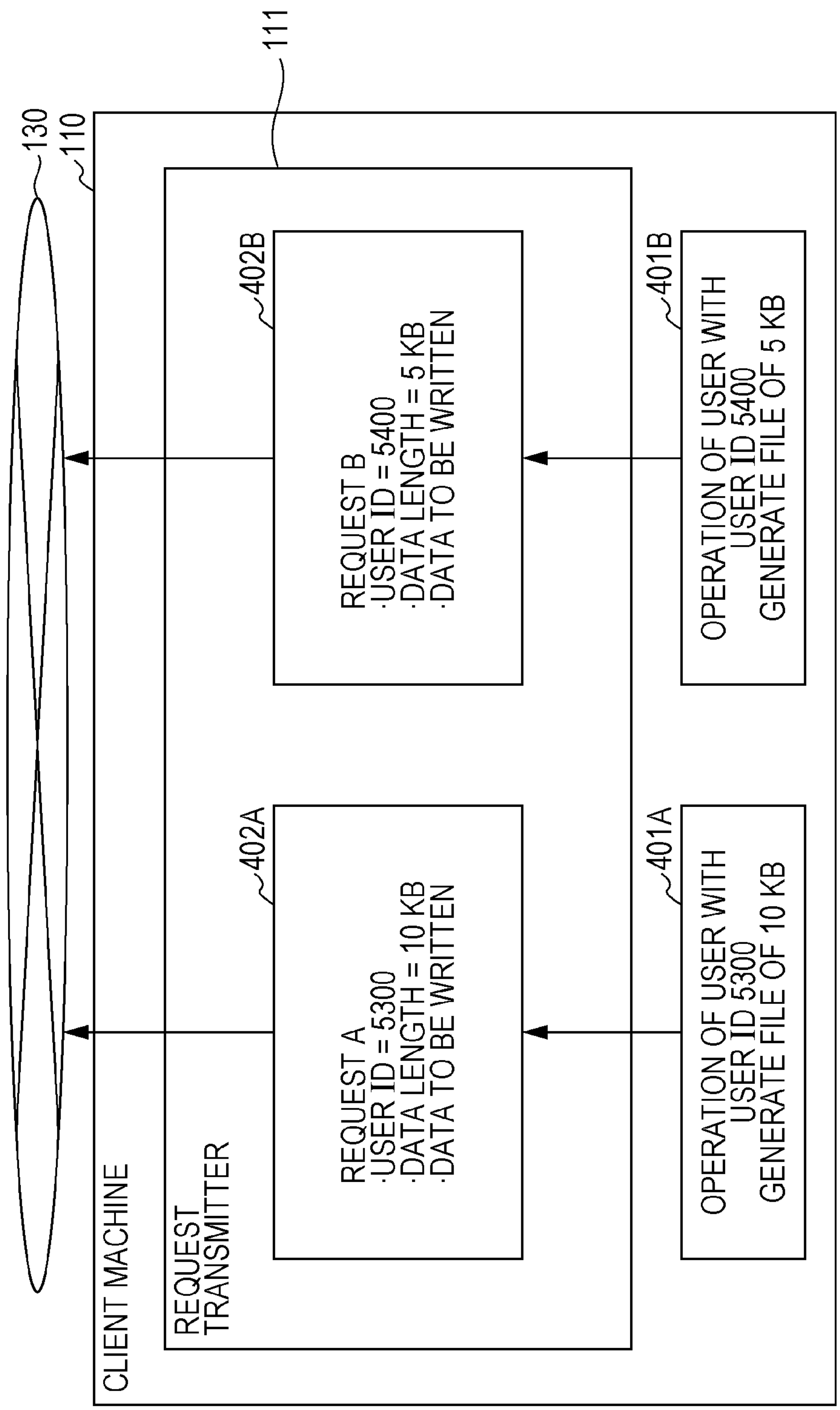

130
110
111
CLIENT MACHINE
REQUEST TRANSMITTER
402A
REQUEST A
·USER ID = 5300
·DATA LENGTH = 10 KB
·DATA TO BE WRITTEN
402B
REQUEST B
·USER ID = 5400
·DATA LENGTH = 5 KB
·DATA TO BE WRITTEN
401A
OPERATION OF USER WITH USER ID 5300
GENERATE FILE OF 10 KB
401B
OPERATION OF USER WITH USER ID 5400
GENERATE FILE OF 5 KB

FIG. 5

OFFSET	DESCRIPTION
0	REQUEST TYPE (WRITE)
8	USER ID
16	SIZE OF DATA TO BE WRITTEN
24	DATA TO BE WRITTEN

FIG. 6

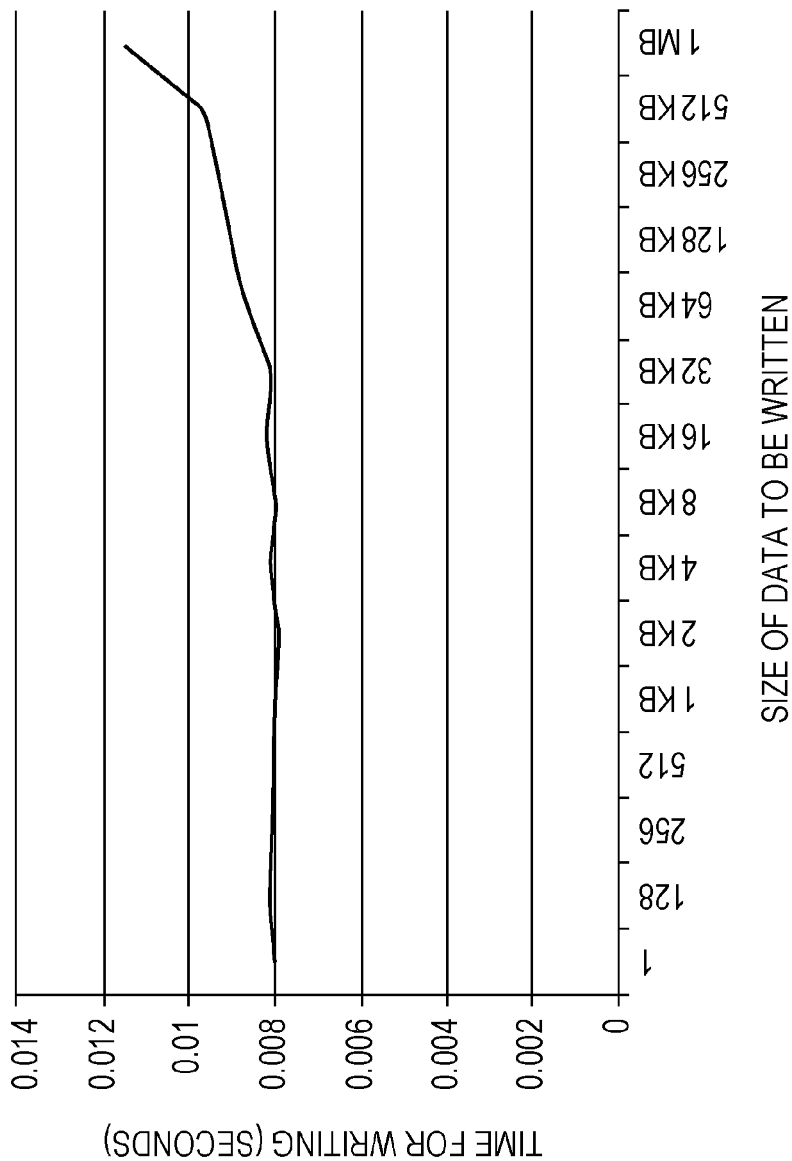

TIME FOR WRITING (SECONDS)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
SIZE OF DATA TO BE WRITTEN
1
128
256
512
1 KB
2 KB
4 KB
8 KB
16 KB
32 KB
64 KB
128 KB
256 KB
512 KB
1 MB

FIG. 7

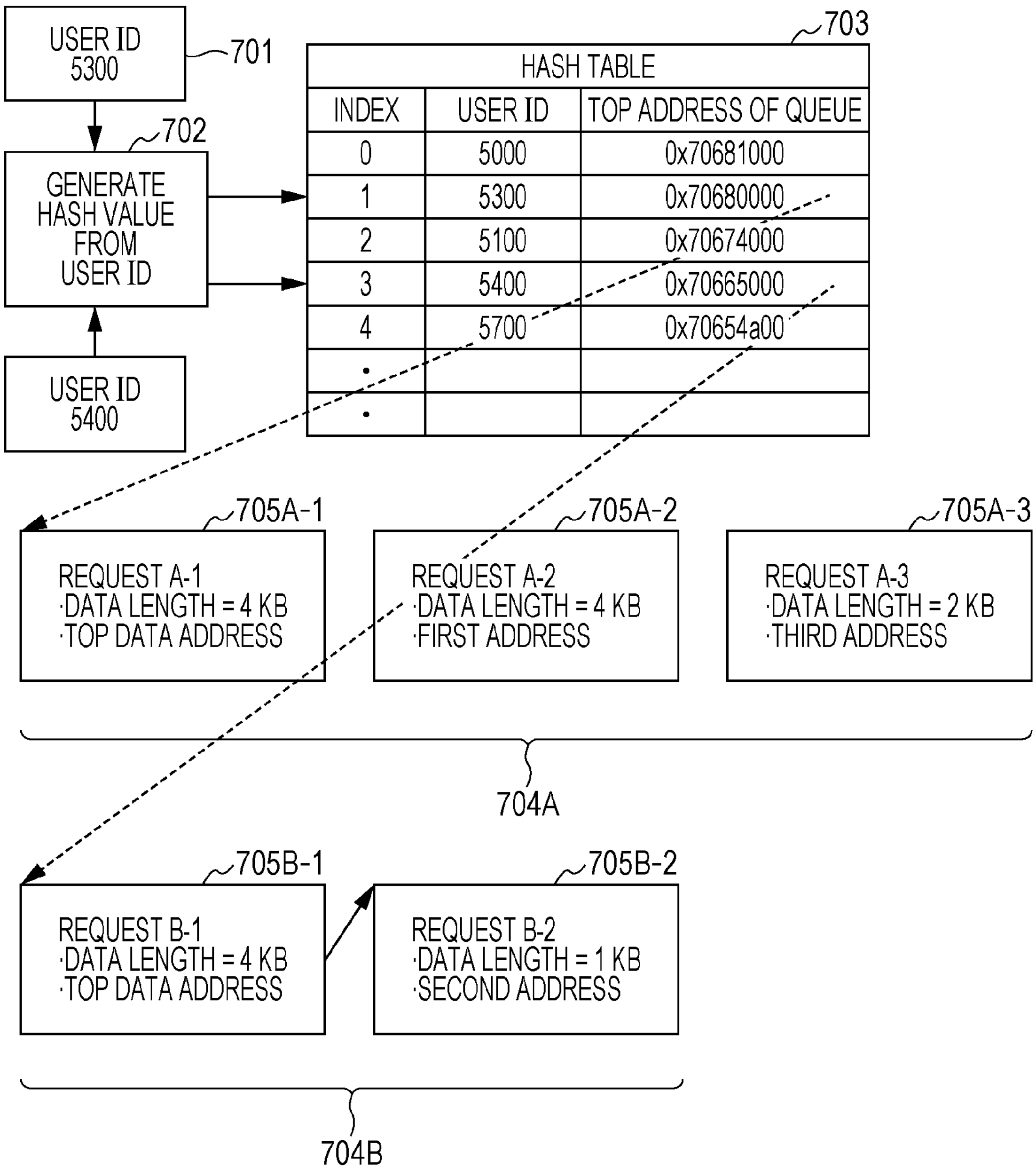

USER ID 5300
701
702
GENERATE HASH VALUE FROM USER ID
USER ID 5400
703
HASH TABLE
INDEX
USER ID
TOP ADDRESS OF QUEUE
0
5000
0x70681000
1
5300
0x70680000
2
5100
0x70674000
3
5400
0x70665000
4
5700
0x70654a00
705A-1
REQUEST A-1
·DATA LENGTH = 4 KB
·TOP DATA ADDRESS
705A-2
REQUEST A-2
·DATA LENGTH = 4 KB
·FIRST ADDRESS
705A-3
REQUEST A-3
·DATA LENGTH = 2 KB
·THIRD ADDRESS
704A
705B-1
REQUEST B-1
·DATA LENGTH = 4 KB
·TOP DATA ADDRESS
705B-2
REQUEST B-2
·DATA LENGTH = 1 KB
·SECOND ADDRESS
704B

FIG. 8

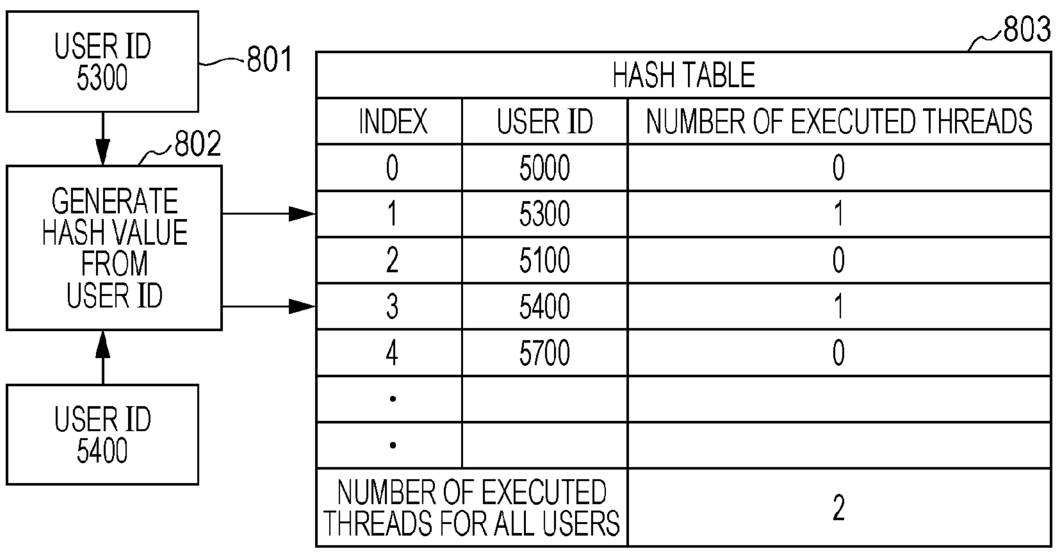

USER ID
5300
801
802
GENERATE
HASH VALUE
FROM
USER ID
USER ID
5400
803
HASH TABLE
INDEX
USER ID
NUMBER OF EXECUTED THREADS
0
5000
0
1
5300
1
2
5100
0
3
5400
1
4
5700
0
NUMBER OF EXECUTED
THREADS FOR ALL USERS
2

FIG. 9

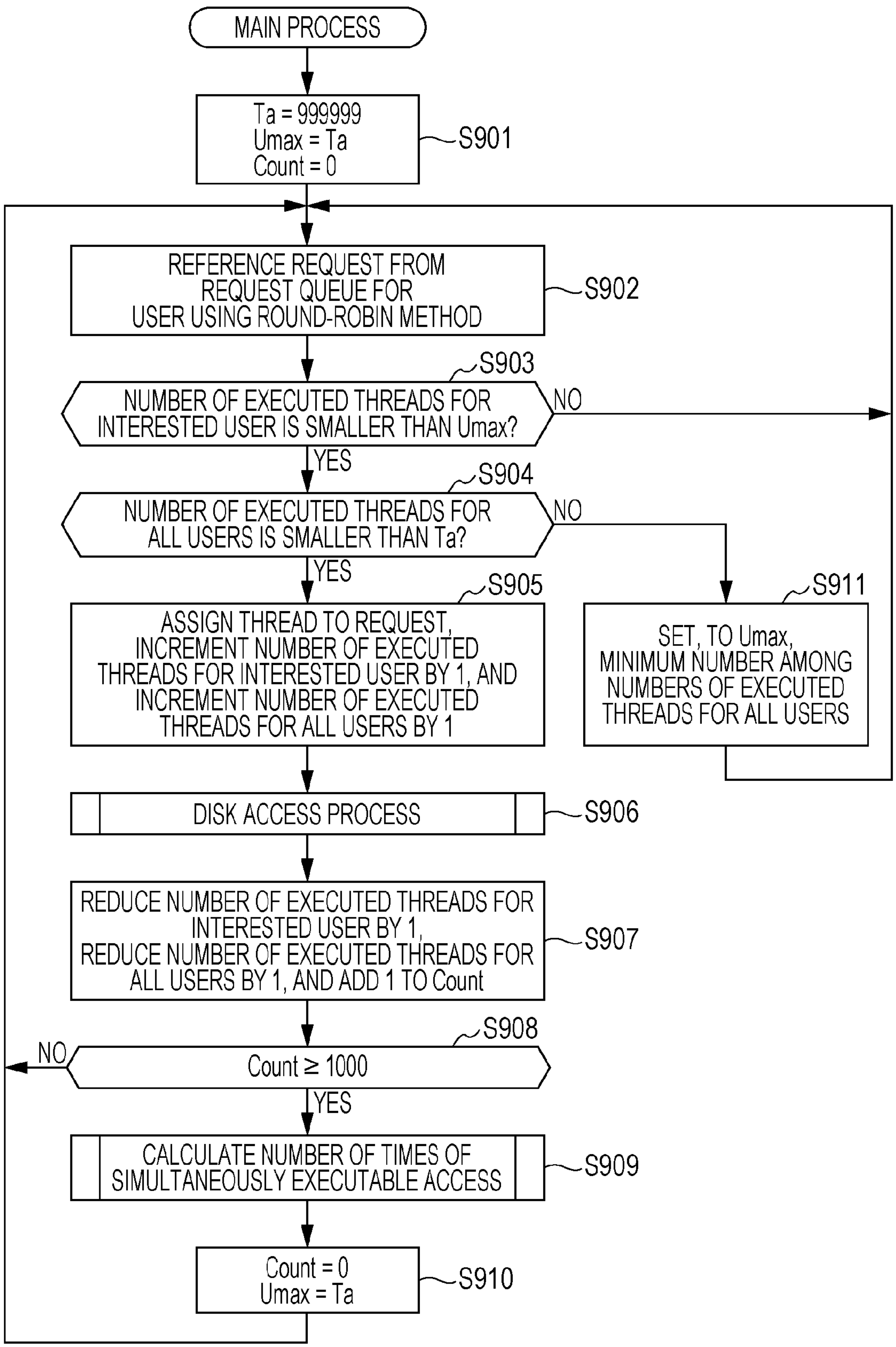

MAIN PROCESS
Ta = 999999
Umax = Ta
Count = 0
S901
REFERENCE REQUEST FROM REQUEST QUEUE FOR USER USING ROUND-ROBIN METHOD
S902
S903
NUMBER OF EXECUTED THREADS FOR INTERESTED USER IS SMALLER THAN Umax?
NO
YES
S904
NUMBER OF EXECUTED THREADS FOR ALL USERS IS SMALLER THAN Ta?
NO
YES
S905
ASSIGN THREAD TO REQUEST, INCREMENT NUMBER OF EXECUTED THREADS FOR INTERESTED USER BY 1, AND INCREMENT NUMBER OF EXECUTED THREADS FOR ALL USERS BY 1
S911
SET, TO Umax, MINIMUM NUMBER AMONG NUMBERS OF EXECUTED THREADS FOR ALL USERS
DISK ACCESS PROCESS
S906
REDUCE NUMBER OF EXECUTED THREADS FOR INTERESTED USER BY 1, REDUCE NUMBER OF EXECUTED THREADS FOR ALL USERS BY 1, AND ADD 1 TO Count
S907
S908
Count ≥ 1000
NO
YES
CALCULATE NUMBER OF TIMES OF SIMULTANEOUSLY EXECUTABLE ACCESS
S909
Count = 0
Umax = Ta
S910

FIG. 10

START TIME OF DISK ACCESS (1001)	END TIME OF DISK ACCESS (1002)	ELAPSED TIME PERIOD (1003)	NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL (1004)
1377993600. 153960	1377993600. 184260	0. 030298	2
1377993600. 168420	1377993600. 194230	0. 025819	2
1377993601. 111370	1377993601. 132590	0. 021219	1
1377993602. 153080	1377993602. 211390	0. 058311	3
1377993602. 155130	1377993602. 215570	0. 060431	3
1377993602. 156170	1377993602. 219690	0. 063521	3

FIG. 11

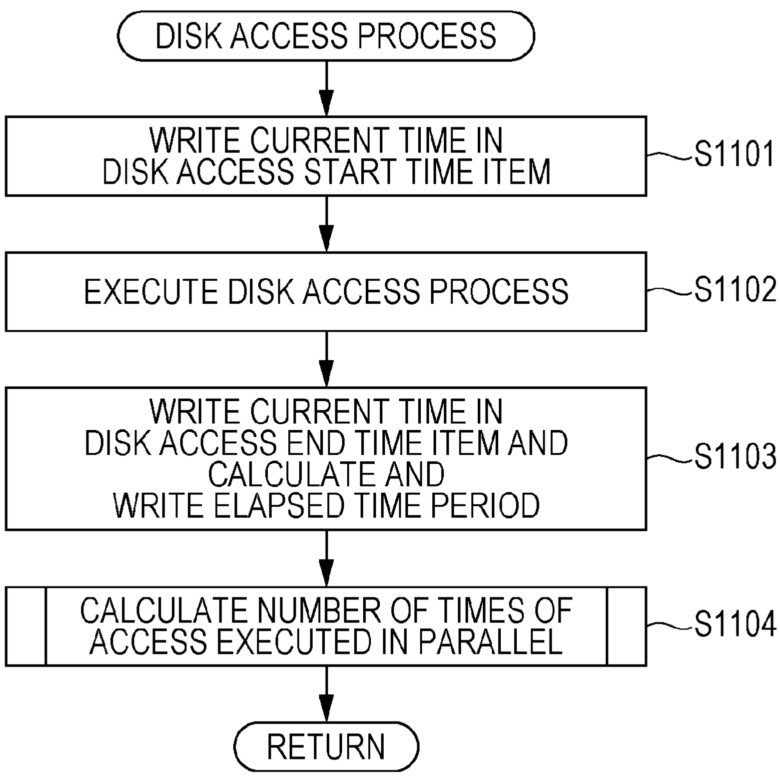

DISK ACCESS PROCESS
WRITE CURRENT TIME IN DISK ACCESS START TIME ITEM
S1101
EXECUTE DISK ACCESS PROCESS
S1102
WRITE CURRENT TIME IN DISK ACCESS END TIME ITEM AND CALCULATE AND WRITE ELAPSED TIME PERIOD
S1103
CALCULATE NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL
S1104
RETURN

FIG. 12

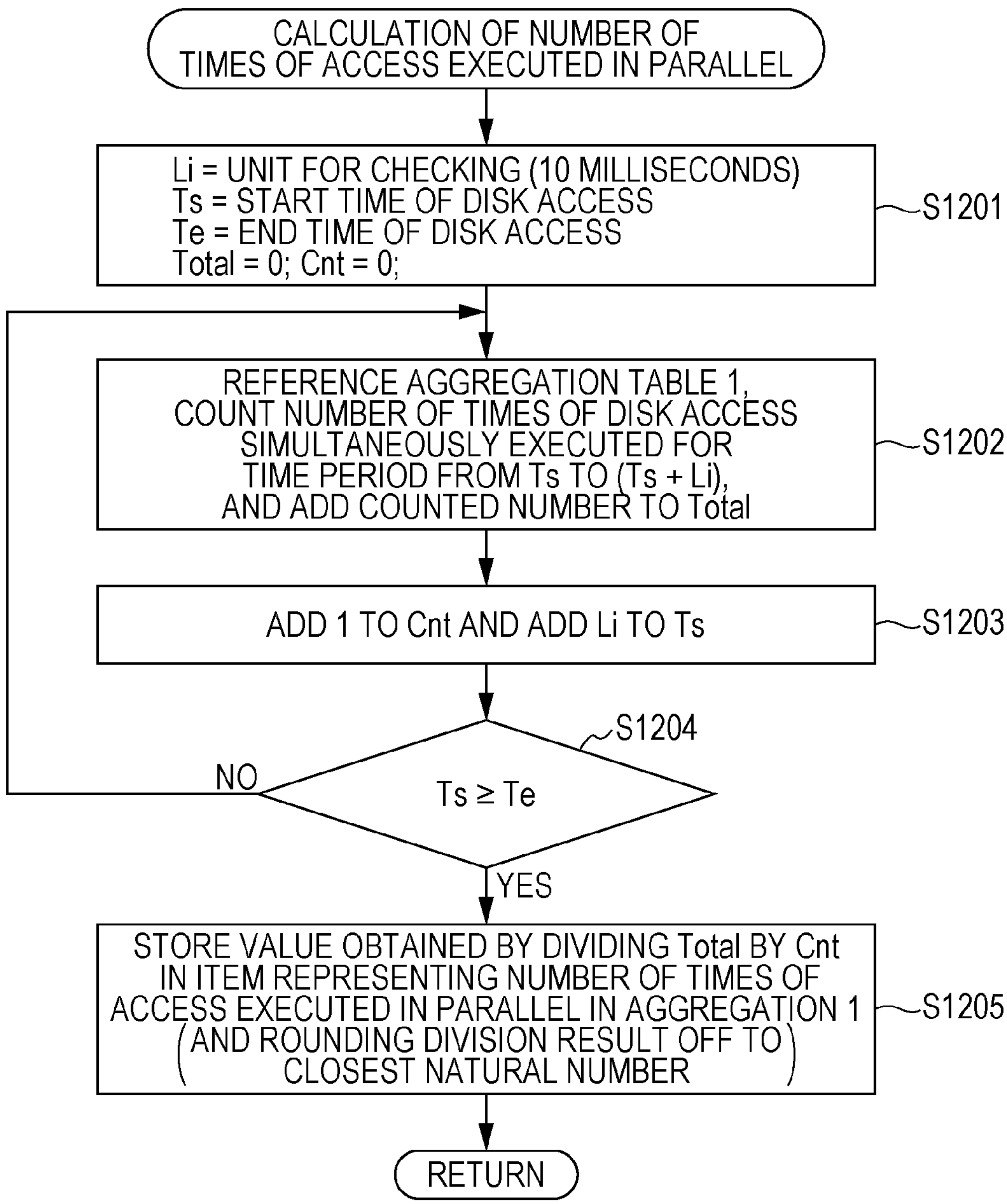

CALCULATION OF NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL
Li = UNIT FOR CHECKING (10 MILLISECONDS)
Ts = START TIME OF DISK ACCESS
Te = END TIME OF DISK ACCESS
Total = 0; Cnt = 0;
S1201
REFERENCE AGGREGATION TABLE 1, COUNT NUMBER OF TIMES OF DISK ACCESS SIMULTANEOUSLY EXECUTED FOR TIME PERIOD FROM Ts TO (Ts + Li), AND ADD COUNTED NUMBER TO Total
S1202
ADD 1 TO Cnt AND ADD Li TO Ts
S1203
S1204
Ts ≥ Te
NO
YES
STORE VALUE OBTAINED BY DIVIDING Total BY Cnt IN ITEM REPRESENTING NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL IN AGGREGATION 1 (AND ROUNDING DIVISION RESULT OFF TO CLOSEST NATURAL NUMBER)
S1205
RETURN

FIG. 13A

1301 1302 1303

NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL	AVERAGE OF ELAPSED TIME PERIODS	RATIO OF AVERAGE OF ELAPSED TIME PERIODS TO AVERAGE OF ELAPSED TIME PERIODS IN WHICH NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL IS 1
1	0.021219	1 TIME
2	0.0280585	1. 32 TIMES
3	0.0607543	2.86 TIMES

FIG. 13B

NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL	AVERAGE OF ELAPSED TIME PERIODS	RATIO OF AVERAGE OF ELAPSED TIME PERIODS TO AVERAGE OF ELAPSED TIME PERIODS IN WHICH NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL IS 1
1	0.021219	1 TIME
2	0	--
3	0	--
4	0.0802534	3.78 TIMES

FIG. 13C

NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL	AVERAGE OF ELAPSED TIME PERIODS	RATIO OF AVERAGE OF ELAPSED TIME PERIODS TO AVERAGE OF ELAPSED TIME PERIODS IN WHICH NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL IS 1
1	0.021219	1 TIME
2	0.0280585	1. 32 TIMES

FIG. 14

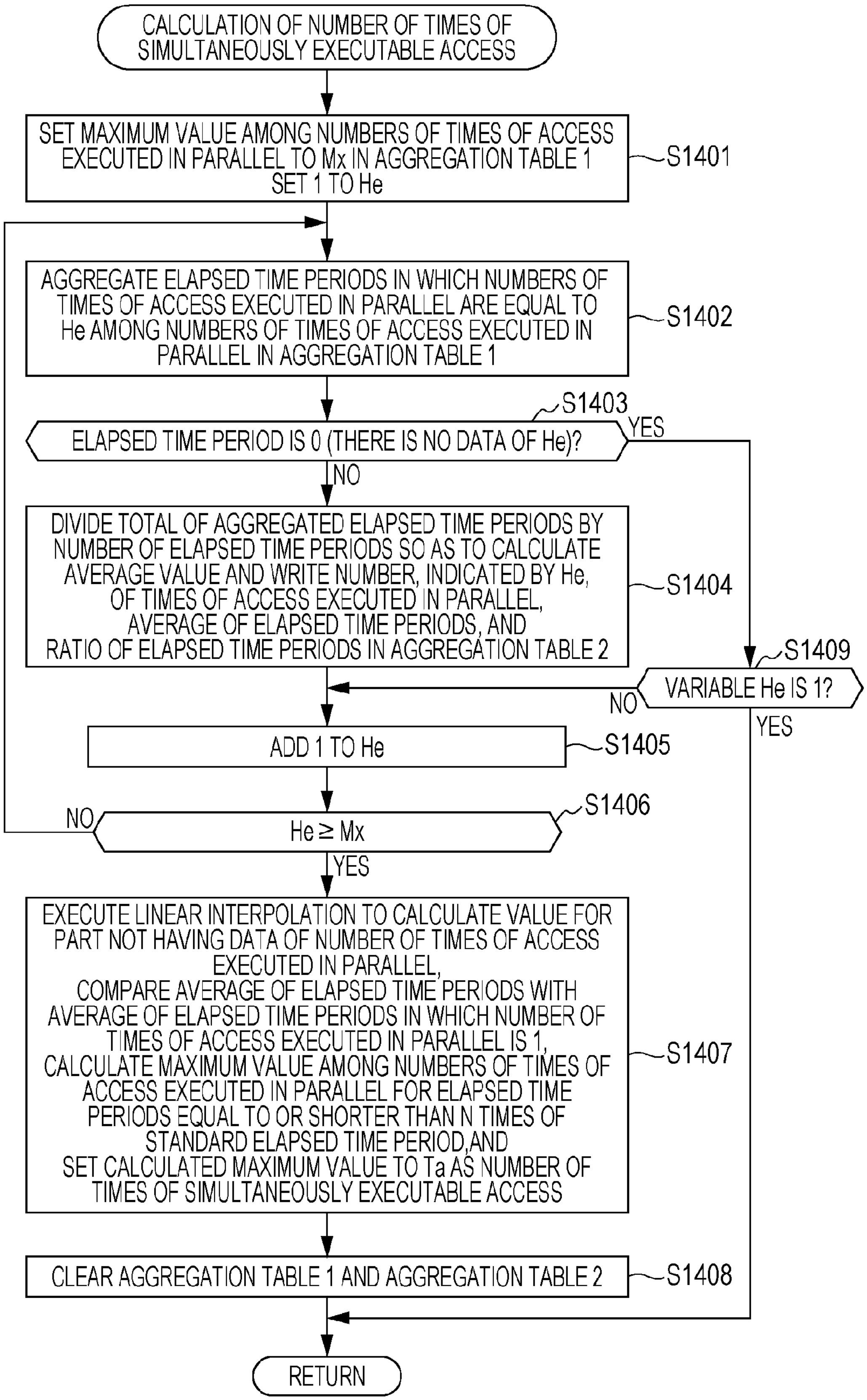
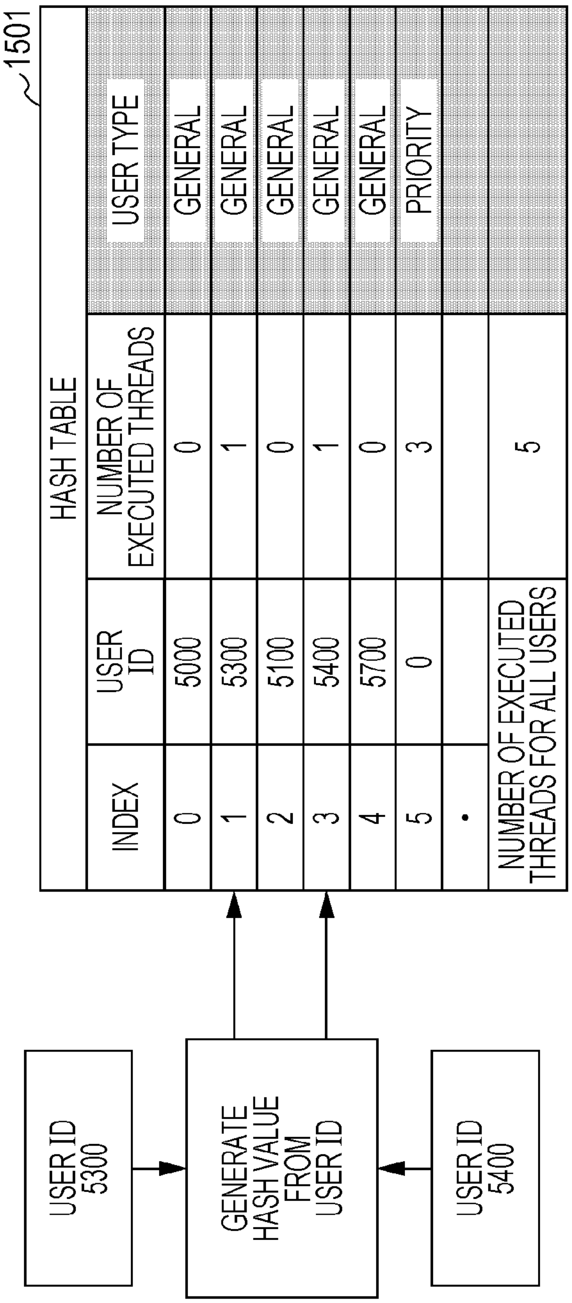

CALCULATION OF NUMBER OF TIMES OF SIMULTANEOUSLY EXECUTABLE ACCESS
SET MAXIMUM VALUE AMONG NUMBERS OF TIMES OF ACCESS EXECUTED IN PARALLEL TO Mx IN AGGREGATION TABLE 1 SET 1 TO He
S1401
AGGREGATE ELAPSED TIME PERIODS IN WHICH NUMBERS OF TIMES OF ACCESS EXECUTED IN PARALLEL ARE EQUAL TO He AMONG NUMBERS OF TIMES OF ACCESS EXECUTED IN PARALLEL IN AGGREGATION TABLE 1
S1402
S1403
ELAPSED TIME PERIOD IS 0 (THERE IS NO DATA OF He)?
YES
NO
DIVIDE TOTAL OF AGGREGATED ELAPSED TIME PERIODS BY NUMBER OF ELAPSED TIME PERIODS SO AS TO CALCULATE AVERAGE VALUE AND WRITE NUMBER, INDICATED BY He, OF TIMES OF ACCESS EXECUTED IN PARALLEL, AVERAGE OF ELAPSED TIME PERIODS, AND RATIO OF ELAPSED TIME PERIODS IN AGGREGATION TABLE 2
S1404
S1409
VARIABLE He IS 1?
NO
YES
ADD 1 TO He
S1405
NO
He ≥ Mx
S1406
YES
EXECUTE LINEAR INTERPOLATION TO CALCULATE VALUE FOR PART NOT HAVING DATA OF NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL, COMPARE AVERAGE OF ELAPSED TIME PERIODS WITH AVERAGE OF ELAPSED TIME PERIODS IN WHICH NUMBER OF TIMES OF ACCESS EXECUTED IN PARALLEL IS 1, CALCULATE MAXIMUM VALUE AMONG NUMBERS OF TIMES OF ACCESS EXECUTED IN PARALLEL FOR ELAPSED TIME PERIODS EQUAL TO OR SHORTER THAN N TIMES OF STANDARD ELAPSED TIME PERIOD,AND SET CALCULATED MAXIMUM VALUE TO Ta AS NUMBER OF TIMES OF SIMULTANEOUSLY EXECUTABLE ACCESS
S1407
CLEAR AGGREGATION TABLE 1 AND AGGREGATION TABLE 2
S1408
RETURN

FIG. 15



INDEX	USER ID	NUMBER OF EXECUTED THREADS	USER TYPE
0	5000	0	GENERAL
1	5300	1	GENERAL
2	5100	0	GENERAL
3	5400	1	GENERAL
4	5700	0	GENERAL
5	0	3	PRIORITY
•			
NUMBER OF EXECUTED THREADS FOR ALL USERS		5	

FIG. 16

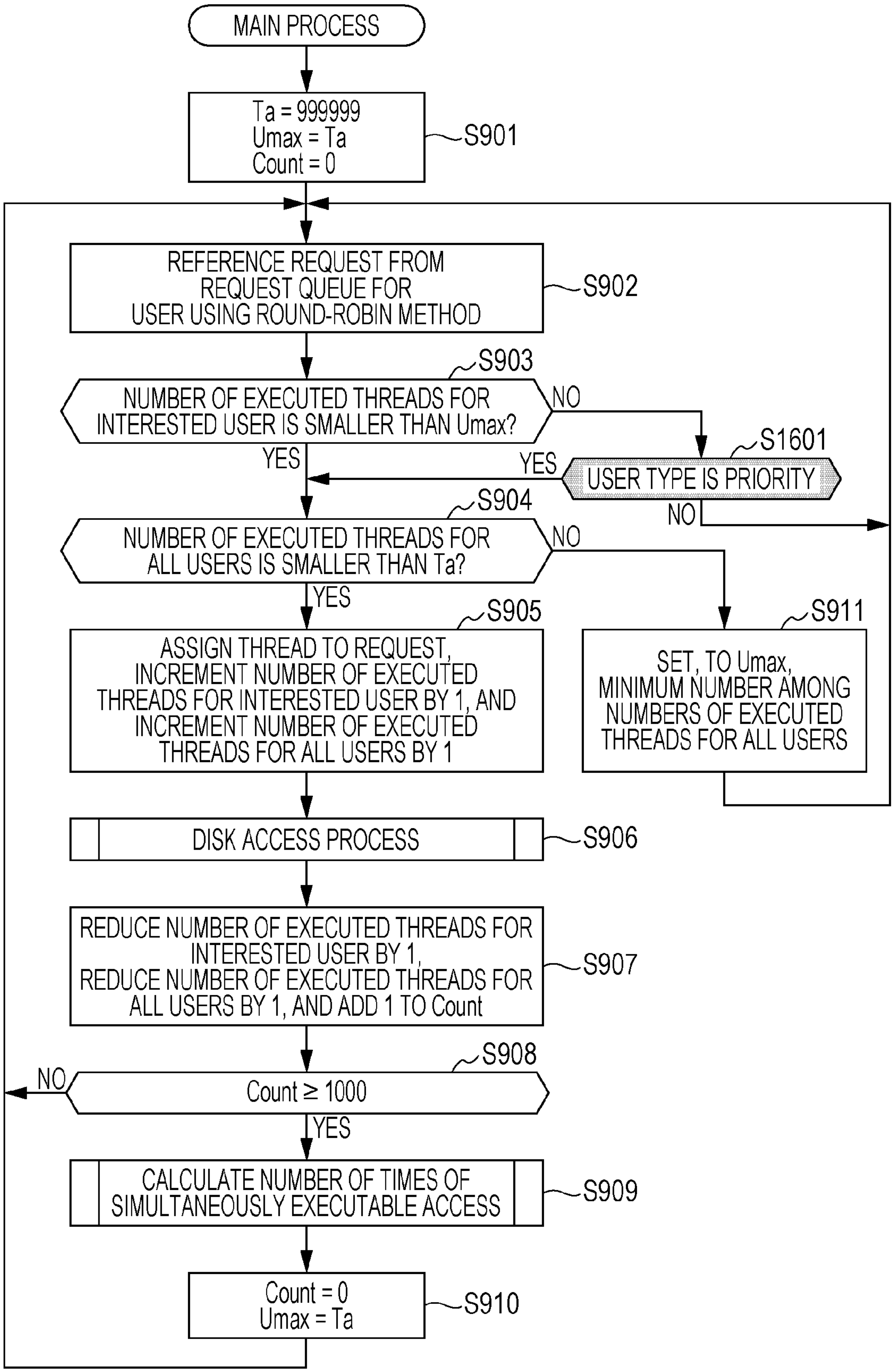
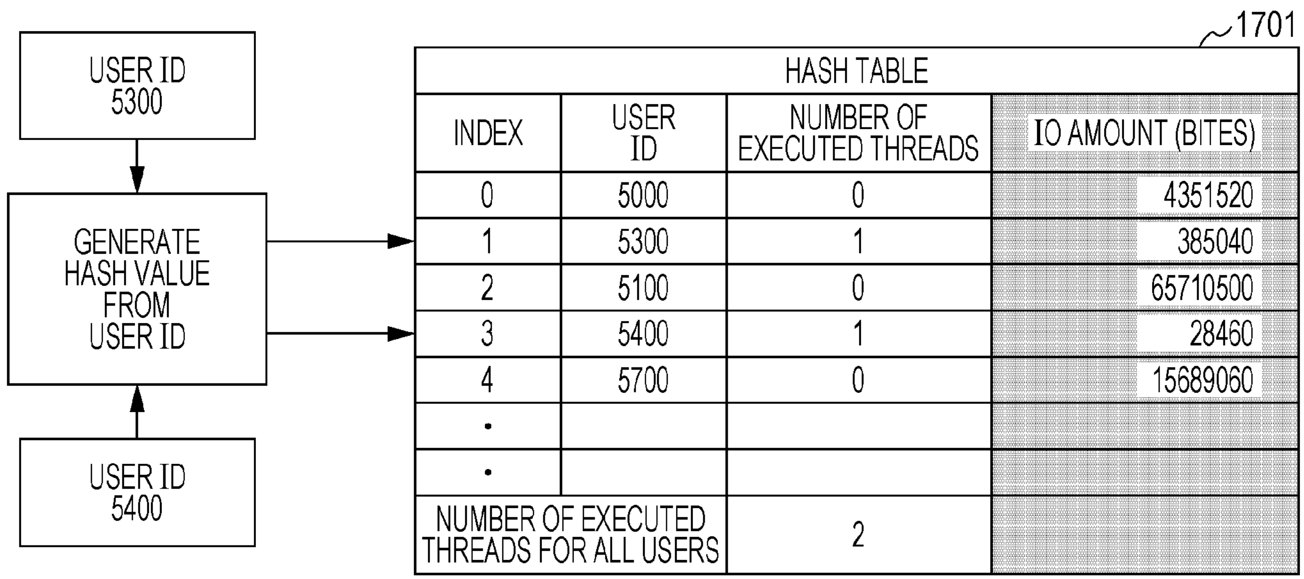
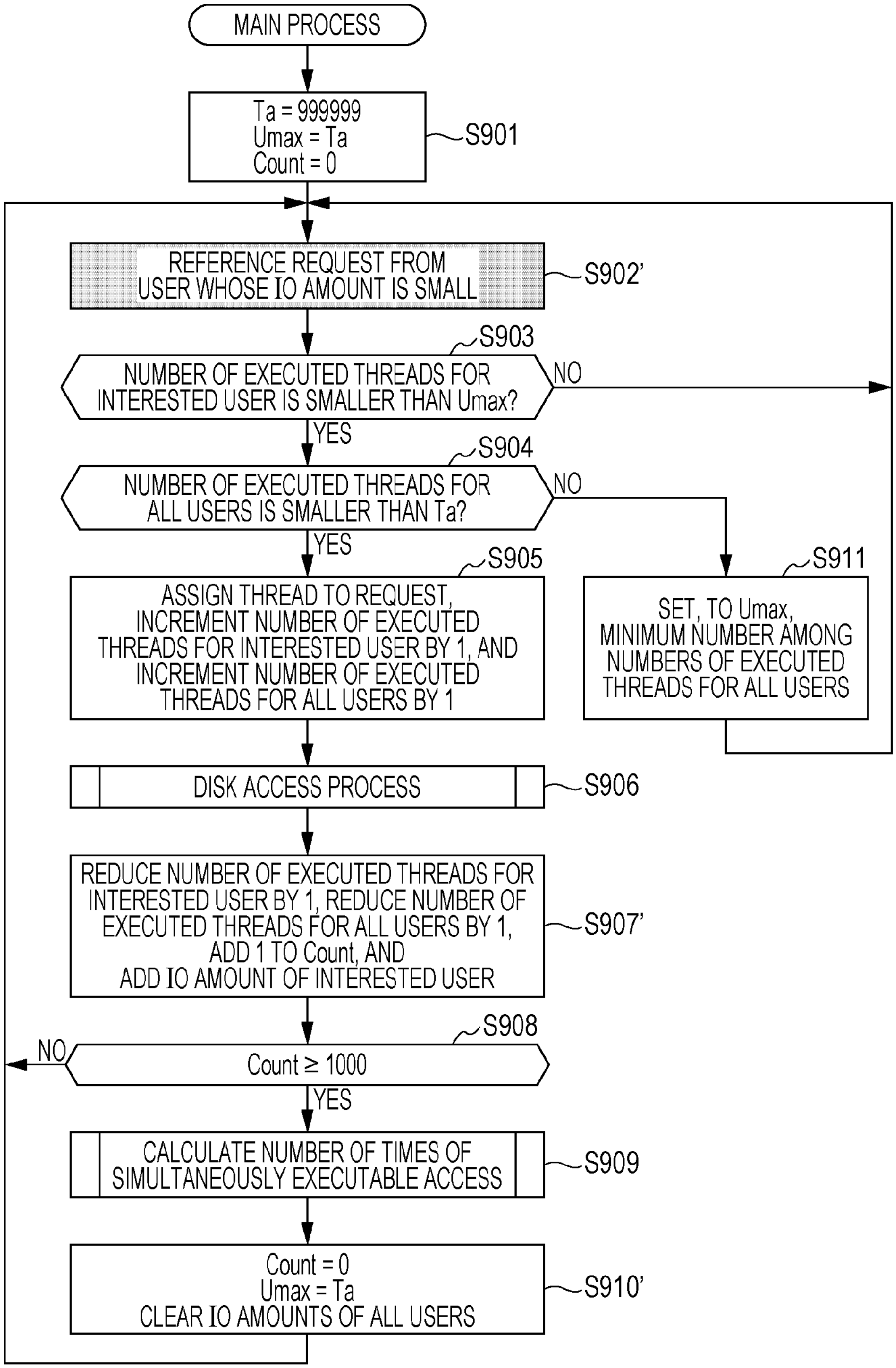

MAIN PROCESS
Ta = 999999
Umax = Ta
Count = 0
S901
REFERENCE REQUEST FROM
REQUEST QUEUE FOR
USER USING ROUND-ROBIN METHOD
S902
S903
NUMBER OF EXECUTED THREADS FOR
INTERESTED USER IS SMALLER THAN Umax?
NO
YES
S1601
USER TYPE IS PRIORITY
YES
NO
S904
NUMBER OF EXECUTED THREADS FOR
ALL USERS IS SMALLER THAN Ta?
NO
YES
S905
ASSIGN THREAD TO REQUEST,
INCREMENT NUMBER OF EXECUTED
THREADS FOR INTERESTED USER BY 1, AND
INCREMENT NUMBER OF EXECUTED
THREADS FOR ALL USERS BY 1
S911
SET, TO Umax,
MINIMUM NUMBER AMONG
NUMBERS OF EXECUTED
THREADS FOR ALL USERS
DISK ACCESS PROCESS
S906
REDUCE NUMBER OF EXECUTED THREADS FOR
INTERESTED USER BY 1,
REDUCE NUMBER OF EXECUTED THREADS FOR
ALL USERS BY 1, AND ADD 1 TO Count
S907
S908
NO
Count ≥ 1000
YES
CALCULATE NUMBER OF TIMES OF
SIMULTANEOUSLY EXECUTABLE ACCESS
S909
Count = 0
Umax = Ta
S910

FIG. 17



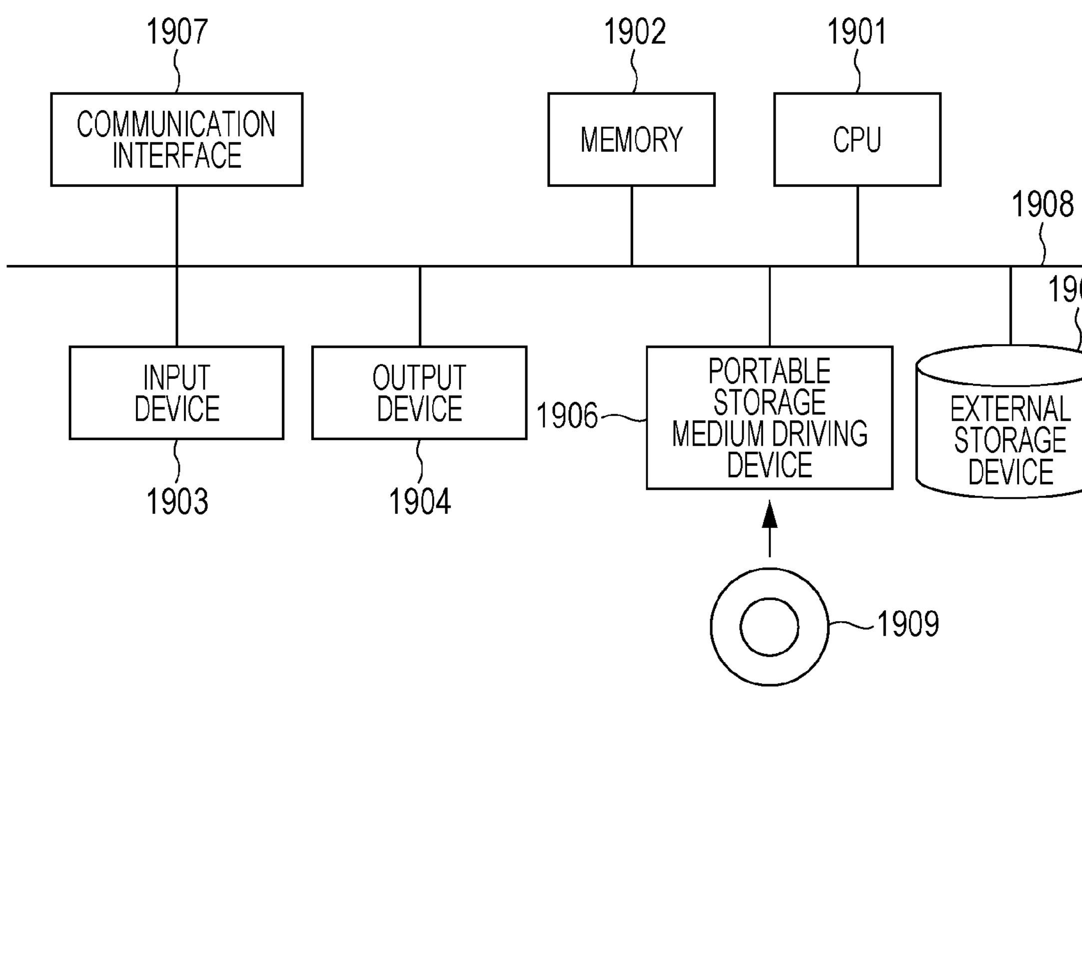
HASH TABLE			
INDEX	USER ID	NUMBER OF EXECUTED THREADS	IO AMOUNT (BITES)
0	5000	0	4351520
1	5300	1	385040
2	5100	0	65710500
3	5400	1	28460
4	5700	0	15689060
•			
•			
NUMBER OF EXECUTED THREADS FOR ALL USERS		2	

FIG. 18



MAIN PROCESS
Ta = 999999
Umax = Ta
Count = 0
S901
REFERENCE REQUEST FROM USER WHOSE IO AMOUNT IS SMALL
S902'
S903
NUMBER OF EXECUTED THREADS FOR INTERESTED USER IS SMALLER THAN Umax?
NO
YES
S904
NUMBER OF EXECUTED THREADS FOR ALL USERS IS SMALLER THAN Ta?
NO
YES
S905
ASSIGN THREAD TO REQUEST, INCREMENT NUMBER OF EXECUTED THREADS FOR INTERESTED USER BY 1, AND INCREMENT NUMBER OF EXECUTED THREADS FOR ALL USERS BY 1
S911
SET, TO Umax, MINIMUM NUMBER AMONG NUMBERS OF EXECUTED THREADS FOR ALL USERS
DISK ACCESS PROCESS
S906
REDUCE NUMBER OF EXECUTED THREADS FOR INTERESTED USER BY 1, REDUCE NUMBER OF EXECUTED THREADS FOR ALL USERS BY 1, ADD 1 TO Count, AND ADD IO AMOUNT OF INTERESTED USER
S907'
S908
NO
Count ≥ 1000
YES
CALCULATE NUMBER OF TIMES OF SIMULTANEOUSLY EXECUTABLE ACCESS
S909
Count = 0
Umax = Ta
CLEAR IO AMOUNTS OF ALL USERS
S910'

FIG. 19


1907
COMMUNICATION INTERFACE
1902
MEMORY
1901
CPU
1908
1905
INPUT DEVICE
1903
OUTPUT DEVICE
1904
1906
PORTABLE STORAGE MEDIUM DRIVING DEVICE
EXTERNAL STORAGE DEVICE
1909

INFORMATION PROCESSING DEVICE, INFORMATION PROCESSING SYSTEM, STORAGE MEDIUM STORING PROGRAM FOR CONTROLLING INFORMATION PROCESSING DEVICE, AND METHOD FOR CONTROLLING INFORMATION PROCESSING DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2014-072265 filed on Mar. 31, 2014, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein are related to an information processing device configured to control access to a device based on a request from a user, an information processing system, a storage medium storing a program for controlling an information processing device, and a method for controlling an information processing device.

BACKGROUND

In a distributed file system such as a network file system (NFS), when a file is accessed from many client machines concurrently, a high load may be applied to a server machine and the rate of the access to the file may be significantly reduced. This is mainly due to the fact that a disk wait period increases due to a conflict in access to a disk device connected to the server machine.

As a technique for controlling access to a file, the following technique is known. A percentage to be used is assigned to each of users, and factors of all applications to be executed by the users are determined. The factors are associated with requests to search data from an arbitrary application. Times to start the requests to search the data are calculated for batches of the data requests in accordance with the associated factors. As a result, the times to start the requests by all users corresponding to the batches are aligned based on the calculated start times. A system readjusts the start times in order for the system to efficiently operate (for example, a technique described in Japanese Laid-Open Patent Publication No. 2000-172541).

A multiplicity is set for each data managing device. A data managing device with a high multiplicity processes a large number of search requests concurrently and processes each search request for a long time, while a data managing device with a low multiplicity processes a smaller number of search requests concurrently and processes each search request for a short time. A service server estimates a processing time for each of search requests from a user terminal, assigns a search request to be processed for a long time to the data managing device with the high multiplicity, assigns a search request to be processed for a short time to the data managing device with the low multiplicity, and thereby improves the efficiency of a search request process. The search request to be processed for the short time is processed and completed by the data managing device with the high multiplicity for the short time. Even if the number of search requests to be concurrently processed is too large, a time for processing the search requests is not too long, compared with the case where the search requests are not concurrently processed, and the number of search requests to be concurrently processed in an overall system increases (for example, a technique described in Japanese Laid-Open Patent Publication No. 2010-152435).

In addition, as techniques for controlling access to a file, there are techniques described in Japanese Laid-Open Patent Publications Nos. 2002-358259, 2006-067401, and 2007-188452, for example.

In the distributed file system, a time for each access may be longer by multiple times than a time for independently executed access. Thus, fairness between users may not be secured, especially when a high load is applied.

SUMMARY

According to an aspect of the invention, an information processing device, comprising: a memory; and one or more central processing units coupled to the memory and configured to: control accesses to a device based on requests from users, record a start time of each access to the device and an end time of the access to the device, determine a load state of the device based on an elapsed time period from the start time to the end time, and limit, based on the load state of the device, a number of threads for one of the users, the threads being concurrently executed to access the device based on access requests to the device from the one of the users.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram illustrating a configuration of a distributed file system according to first to third embodiments;

FIG. **2** is a diagram illustrating a specific example of the calculation of the number of times of file access executed in parallel for each of elapsed time periods;

FIG. **3** is a diagram describing operations of controlling the number of executed threads for all users and the number of executed threads for each of the users;

FIG. **4** is an explanatory diagram illustrating a request transmitter;

FIG. **5** is a diagram illustrating an example of a data format of a request;

FIG. **6** is a diagram illustrating an example of a graph of time periods for writing data with respect to the sizes of the data to be written if a third extended (EXT3) file system (a block size=4 KB) is provided;

FIG. **7** is a diagram describing request management by a request receiver;

FIG. **8** is a diagram illustrating an example of a data configuration of a hash table;

FIG. **9** is a flowchart of a detailed example of a process of controlling the assignment of threads;

FIG. **10** is a diagram illustrating an example of a data configuration of an aggregation table;

FIG. **11** is a flowchart of a detailed example of a disk access process;

FIG. **12** is a flowchart of a detailed example of a process of calculating the number of times of disk access executed in parallel;

FIGS. **13**A, **13**B, and **13**C are diagrams illustrating an example of a data configuration of another aggregation table;

FIG. **14** is a flowchart of a detailed example of a process of calculating the number of times of parallel executable access;

FIG. **15** is a diagram illustrating an example of a data configuration of a hash table according to the second embodiment;

FIG. **16** is a flowchart of a detailed example of a process of controlling the assignment of threads according to the second embodiment;

FIG. **17** is a diagram illustrating an example of a data configuration of a hash table according to the third embodiment;

FIG. **18** is a flowchart of a detailed example of a process of controlling the assignment of threads according to the third embodiment; and

FIG. **19** is a diagram illustrating an example of a hardware configuration of a server machine that may achieve a distributed file system provided with functions illustrated in FIG. **1**.

DESCRIPTION OF EMBODIMENTS

In a distributed file system, when a disk device is accessed in concurrent from many points, a processing time per each access is longer by multiple times than a processing time for independently executed access, and thus a response may be delayed. Thus, when a high load is applied, processing of a small amount (IO amount) of data to be input and output in accordance with an operation by a user may be significantly delayed due to processing of a large amount (IO amount) of data to be input and output in accordance with an operation by another user. Thus, fairness between the users may be secured.

Hereinafter, first to third embodiments are described with reference to the accompanying drawings.

FIG. **1** is a diagram illustrating a configuration of a distributed file system according to the first to third embodiments. The distributed file system includes a server machine **100** configured to access, in a shared manner, a disk device **120** that is an external storage device with a RAID system, for example. The distributed file system includes at least one client machine **110** connected to the server machine **100** through a network **130** such as a local area network (LAN) or the Internet, for example. The client machine **110** issues, to the server machine **100**, a request to access the disk device **120**. The request is a request to write file data in the disk device **120**, a request to read file data from the disk device **120**, or the like, for example.

The server machine **100** includes a request receiver **101**, a thread assignment controller **102**, a disk access time recorder **103**, a disk load state analyzer **104**, an access time record table **105**, and server threads **106**. The client machine **110** includes a request transmitter **111**.

The disk access time recorder (access recorder) **103** records start times of access to the disk device (device) **120** and end times of the access to the disk device **120** in the access time record table **105** stored in a memory of the server machine **100**, for example. When multiple requests to execute access are provided from users, the disk access time recorder **103** records start times of the access and end times of the access in the access time record table **105**, for example.

The disk load state analyzer (load state analyzer) **104** determines a load state of the disk device **120** based on elapsed time periods from the start times recorded in the access time record table **105** to the end times recorded in the access time record table **105**, for example.

The thread assignment controller **102** limits, based on the load state of the disk device **120** to be accessed based on a request from a user, the number of threads that are concurrently executed to access the disk device **120**. The request is transmitted from the request transmitter **111** included in the client machine **110** operated by the user, received by the request receiver **101** included in the server machine **100** through the network **130**, and transferred to the thread assignment controller **102**, for example. The thread assignment controller **102** limits the number of server threads **106** that are concurrently executed on the server machine **100** for each user in order to access the disk device **120**.

According to the aforementioned configuration, the disk load state analyzer **104** may dynamically analyze the load state of the disk device **120** based on a change of the state of the disk device **120**. The state of the disk device (device) **120** is, for example, the number of times of access and may cause a temporal change of response performance and the like of the disk device **120**. In the first embodiment, concurrent access control that is fair for the users is achieved by limiting, based on load states calculated for temporally changing states of the disk device **120**, the number of threads that are concurrently executed to access the disk device **120** based on the request from the user. This is due to the fact that it is possible to calculate the number (number of times of concurrently executable access), suppressing a delay of access with respect to a time to access the disk device **120**, of times of access executed in concurrent.

In the aforementioned configuration, the request receiver **101** may divide a data size of a request transmitted from the client machine **110** into certain sizes causing time periods for access to the disk device **120** to be within certain time periods and issue, to the disk device **120**, requests to access the disk device **120**. This control inhibits a variation in the time periods for the access. The certain time periods are each approximately 10 milliseconds, for example. The certain sizes are each equal to a block size of a file system of the disk device **120**, for example.

The disk access time recorder **103** counts, for each access issued by server threads **106**, the number of times of the interested and other access, issued by server threads **106** and executed in concurrent, to the disk device **120** for the interested access for each of the certain time periods within an elapsed time period for the interested access from a start time of the access issued by a server thread **106** and an end time of the access issued by the server thread **106**. The disk access time recorder **103** calculates, for each access, an average of the numbers of times of the access executed in concurrent within the overall elapsed time period for the interested access based on the counted number of times of the access executed in concurrent for each of the certain time periods and thereby calculates, for each access, the number of the times of the access executed in concurrent within the overall elapsed time period for the interested access, for example.

The disk load state analyzer **104** calculates the number of times of concurrently executable access when the total of the numbers of times of access executed in concurrent within an elapsed time period for each access becomes a certain value. For example, the disk load state analyzer **104** compares an elapsed time period for independently executed access with elapsed time periods for access executed in concurrent among the time periods for the access and determines, as the number of times of concurrently executable access, the number of times of access executed in concurrent within an elapsed time period that is equal to or shorter than N (N>0) times of the elapsed time period for the independently executed access among the numbers of times of access executed in concurrent. Specifically, the disk load state analyzer **104** determines the load state of the disk device **120** by determining the number of times of concurrently executable access. The disk load state analyzer **104** may appropriately detect temporally changing load states of disks by repeating the analysis of the load state at certain time intervals.

The thread assignment controller **102** limits the number of concurrently executed server threads **106** so as to ensure that the number of the concurrently executed server threads **106** does not exceed the number of times of concurrently executable access.

After the disk load state analyzer **104** determines the number of times of concurrently executable access, records of the access time record table **105** are cleared. Then, the thread assignment controller **102** limits, based on the determined number of times of concurrently executable access, the number of concurrently executed server threads **106**. The disk access time recorder **103** restarts recording an access time period in the access time record table **105** for each access and calculates, for each access, the number of times of access executed in concurrent within an elapsed time period for the interested access. When the total of the numbers of times of access executed in concurrent within an elapsed time period for each access becomes the certain value again, the disk load state analyzer **104** aggregates the elapsed time periods for the numbers of the times of the access executed in concurrent and recalculates the number of times of concurrently executable access based on the result of the aggregation. Even if a delay of disk access is not reduced by calculating the number of times of concurrently executable access once, the load state of the disk device **120** may be more accurately determined by calculating the number of times of concurrently executable access multiple times.

In this manner, concurrent access control that is executed based on a change in the state of the disk device **120** and is fair for the users is achieved by repeating the calculation of the number of times of concurrently executable access. Access fairness between the users is secured by controlling time periods for access and thereby causing the time periods for the access to be equal to or shorter than N times of the elapsed time period of independently executed access. Specifically, when the number of executed threads does not exceed the total number of executed threads accepted by the system, the number of times of access executed in concurrent for each user is limited and the number of threads for a user who causes a high load is limited. Thus, even a user who causes a low load may access the disk device **120** and thus the fairness may be achieved. The state of the disk device **120** includes the aforementioned number of times of access from the user, failure statuses of disks forming the RAID system, the type of the request causing the access, and the like. In the first embodiment, the number (number of concurrently executed threads) of executed threads is limited, and thus an increase in a processing time per each access is suppressed. Thus, the occurrence of a delay of a response by the file system may be suppressed.

FIG. **2** is a diagram illustrating a specific example of the calculation of the number of times of access executed in concurrent for each of elapsed time periods for file access by the disk access time recorder **103**. This example assumes that the lengths of all data are equal to each other.

In the example illustrated in FIG. **2**, after a time of 10 milliseconds elapses after the start of the execution of file access **1**, the execution of file access **2** is started with a cross call. The number of times of file access executed in concurrent for a time period from 0 to 10 milliseconds is 1, the number of times of file access executed in concurrent for a time period from 10 milliseconds to 30 milliseconds is 2, and the number of times of file access executed in concurrent for a time period from 30 milliseconds to 40 milliseconds is 1. An elapsed time period for the file access 1 is 30 milliseconds. An average of the numbers of times of file access executed in concurrent for time periods from 0 to 30 milliseconds is calculated according to the following equation, while the time periods are each 10 milliseconds.

The average of the numbers of times of access executed in concurrent for the file access 1=(1+2+2)/3=1.67 and the elapsed time period for the file access 1 is 30 milliseconds.

Similarly, an average of the numbers of times of access executed in concurrent for file access 2=(2+2+1)/3=1.67 and an elapsed time period for the file access 2 is 30 milliseconds.

An average of the numbers of times of access executed in concurrent for the file access 3=(1+1+1)/3=1 and an elapsed time period for the file access 3 is 30 milliseconds.

An average of the numbers of times of access executed in concurrent for a file access 4=(1+3+4+5)/4 =3.25 and an elapsed time period for the file access 4 is 40 milliseconds.

An average of the numbers of times of access executed in concurrent for a file access 5=(3+4+5+4+4)/5=4 and an elapsed time period for the file access 5 is 50 milliseconds.

An average of the numbers of times of access executed in concurrent for a file access 6=(3+4+5+4+4)/5=4 and an elapsed time period for the file access 6 is 50 milliseconds.

An average of the numbers of times of access executed in concurrent for a file access 7=(4+5+4+4+2+2)/6=3.5 and an elapsed time period for the file access 7 is 60 milliseconds.

An average of the numbers of times of access executed in concurrent for a file access 8=(5+4+4+2+2)/5=3.4 and an elapsed time period for the file access 8 is 50 milliseconds. Equations (1)

In the example illustrated in FIG. **2**, the calculated average of the numbers of times of access executed in concurrent for the file access 3 is 1, and the file access **3** is independently executed (or is not executed in concurrent with other file access) for the elapsed time period for the file access **3** as illustrated in FIG. **2**. In the example illustrated in FIG. **2**, if it is assumed that the number of times of access to be processed in parallel in the disk device **120** with a cross call is up to 2, the request receiver **101** keeps file access waiting in a request queue on a memory managed by the request receiver **101** for time periods, indicated by "wait" in FIG. **2**, of 10 milliseconds. Thus, the elapsed time periods for the file access **4** to **8** are each longer than the original time period of 30 milliseconds.

In the aforementioned calculation example of Equations (1) for the file access **1** to **8**, a correlation between an average of the numbers of times of access executed in concurrent for interested access and an elapsed time period for the interested access may be obtained. According to the correlation, when the average of the numbers of times of access executed in concurrent for the interested access increases and exceeds the number of times of concurrently executable access accepted by the system, and the number of times of access kept waiting increases, an elapsed time period for the interested access increases. For example, it is sufficient if the following control is executed based on the correlation in order to suppress an increase in a delay of access to the disk device **120**. It is sufficient if the numbers of times of access, executed in concurrent, to the disk device **120** are controlled so as to ensure that elapsed time periods for the access are equal to or shorter than N times of the elapsed time period for independently executed access or N times of the elapsed time period in which the number of times of access executed in concurrent is 1. In this case, N is 1.5, 2, or the like, for example.

In general, when the number of times of access, executed in concurrent, to the disk device **120** increases, a processing time per each access is longer by a certain value or more than a processing time for independently executed access, and a delay of a response by the file system occurs. Thus, access to the disk device **120** is biased toward a user who causes a high load, and disk access by a user who causes a low load may be inhibited. In the first embodiment, the data size of the request is divided into the certain sizes, requests are issued, and a time period for each access to the disk device **120** may be a certain time period (of, for example, 10 milliseconds). Thus, the number of times of access executed in concurrent for each of the certain time periods may be accurately calculated. A time for a response to access may be controlled to be equal to or shorter than N times of a time period for a response to independently executed access by limiting the number of times of concurrently executable access based on the number of times of access executed in concurrent for each of the certain time periods. In addition, requests to execute access that are provided by users may be fairly processed while time periods for responses to the access are equal to or shorter than N times of the time for the response to the independently executed access. In the first embodiment, since the numbers of times of access, executed in concurrent, to the disk device **120** are limited, delays of responses to requests may be suppressed and the numbers of the times of the access executed in concurrent may be controlled so as to avoid the fact that only the numbers of times of access executed in concurrent based on requests from users who cause a high load increase. In the calculation example of the aforementioned Equations (1), an elapsed time period in which the number of times of access executed in concurrent is 1 is the elapsed time period for the file access **3** and is 30 milliseconds. If N=1.5, 1.5 times of the elapsed time period in which the number of times of access executed in concurrent is 1 is 30 milliseconds×1.5=45 milliseconds. The disk load state analyzer **104** selects the maximum value among the averages of the numbers of times of access executed in concurrent for the file access executed for time periods of 45 milliseconds or less in the calculation example of the aforementioned Equations (1). As a result, in the calculation example of the aforementioned Equations (1), the average of the numbers of the times of the access executed in concurrent for the file access **4** executed for the elapsed time period of 40 milliseconds is selected and is 3.25. As described above, the thread assignment controller **102** controls the number of concurrently executed server threads **106** and thereby controls access to the disk device **120**. The disk load state analyzer **104** determines, as the number of times of concurrently executable access, an integer "3" of 3.25 that is the selected average of the numbers of the times of the access executed in concurrent and notifies the thread assignment controller **102** of the integer "3".

The thread assignment controller **102** limits the number of concurrently executed server threads **106** so as to ensure that the limited number does not exceed the notified number "3" that is the number of times of concurrently executable access.

After that, the number of times of concurrently executable access is changed to 3, and details included in the access time record table **105** stored on the memory and corresponding to the calculation results of the aforementioned Equations (1) are cleared. Then, when the total of the numbers of times of file access becomes equal to a certain value, the number of times of concurrently executable access is recalculated in the aforementioned manner, and it is determined whether the recalculated number of times of concurrently executable access is valid.

In the configuration of the distributed file system illustrated in FIG. **1**, the thread assignment controller **102** may count the number of concurrently executed server threads **106** for each of the users and the number of concurrently executed server threads **106** for all the users. In this case, the thread assignment controller **102** may process requests while the number, counted for all the users, of concurrently executed threads does not exceed the number, notified by the disk load state analyzer **104**, of times of concurrently executable access. When requests that cause the number, calculated for all the users, of times of concurrently executed threads to exceed the number of times of concurrently executable access are provided, the thread assignment controller **102** may execute the following control operation. That is, the thread assignment controller **102** reduces, based on the minimum number, counted for a user, of times of concurrently executed threads among the numbers, counted for the users, of times of concurrently executed threads, the numbers of times of concurrently executed server threads **106** based on requests from the other users.

FIG. **3** is a diagram describing operations of controlling the number (number of concurrently executed threads) of executed threads for all the users and the numbers (number of concurrently executed threads) of executed threads for each of the users.

The thread assignment controller **102** activates a server thread **106** for each of requests issued by the request receiver **101** at time intervals of, for example, 10 milliseconds, based on a request from the request transmitter **111** included in the client machine **110** (illustrated in FIG. **1**) operated by the user. The thread assignment controller **102** limits the number of concurrently executed server threads **106** for each of the users and the number of concurrently executed server threads **106** for all the users.

More specifically, the thread assignment controller **102** executes the following control operation when activating a server thread **106** based on a request newly input to the thread assignment controller **102** from the request receiver **101**.

First, the thread assignment controller **102** executes a process **302** of generating a hash value for a user ID **301** added to the aforementioned input request. For example, a hash value "1" is generated from a value "5300" of the user ID **301**.

The thread assignment controller **102** searches, on a hash table **303** stored in the memory of the server machine **100**, a record having the generated hash value in an INDEX item.

If the interested record does not exist on the hash table **303**, the thread assignment controller **102** executes the following process. First, the thread assignment controller **102** generates a new record on the hash table **303** and registers the aforementioned hash value in an INDEX item of the generated record. In addition, the thread assignment controller **102** secures a storage region **304** (**304**(#**1**), **304** (#**2**), or the like) for storing the number (number of concurrently executed threads) of executed threads corresponding to the user ID from which the hash value has been generated.

Note that an initial value of the storage region **304** is set to 0. Then, the thread assignment controller **102** registers a pointer value indicating an address of the secured storage region **304** in a pointer item of the record newly generated on the hash table **303**. Then, the thread assignment controller **102** acquires the pointer value. For example, a storage region **304**(#**1**) is secured for the hash value "1", while the hash value "1" and the pointer value "0x60680000" are registered in the new record on the hash table **303**. Alternatively, for example, a storage region **304**(#**2**) is secured for a hash value "2", while the hash value "2" and a pointer value "0x60674000" are registered in a new record on the hash table **303**. The same applies to other records on the hash table **303**.

When finding the record having the aforementioned hash value in the INDEX item on the hash table **303**, the thread assignment controller **102** acquires the pointer value registered in the record.

The thread assignment controller **102** increments, by 1, the number, stored in the storage region **304** on the memory at the address indicated by the pointer value acquired from the hash table **303** and corresponding to the user ID from which the hash value has been generated, of executed threads. Concurrently, the thread assignment controller **102** increments, by 1, the number, corresponding to all the users and stored in a storage region **305** on the memory of the server machine **100**, of executed threads.

The thread assignment controller **102** executes the following control operation every time access to the disk device **120** by a server thread **106** is completed.

First, the thread assignment controller **102** executes the process **302** of generating the hash value for the user ID **301** corresponding to the server thread **106** that has completed the access.

The thread assignment controller **102** searches the record having the generated hash value in the INDEX item on the hash table **303** stored on the memory of the server machine **100** and acquires the pointer value registered in the record.

Since the access has been completed, the thread assignment controller **102** reduces, by 1, the number, stored in the storage region **304** at the address indicated by the pointer value acquired from the hash table **303** on the memory and corresponding to the user ID from which the hash value has been generated, of executed threads. Concurrently, the thread assignment controller **102** reduces, by 1, the number, stored in the storage region **305** and corresponding to all the users, of executed threads.

The thread assignment controller **102** executes the following control process before managing the increase and reduction in the number of executed threads.

The thread assignment controller **102** controls the numbers, stored in storage regions **304**, of executed threads for user IDs #**1**, #**2**, . . . and thereby inhibits the numbers of the executed threads for the users IDs from exceeding the maximum number, stored in a storage region **307** on the memory of the server machine **100**, of threads assignable to one user (**306** in FIG. **3**).

Specifically, when receiving a request from the request receiver **101**, the thread assignment controller **102** references, through the hash table **303**, the number, stored in a storage region **304** corresponding to a user ID added to the request, of executed threads.

If the number, stored in the aforementioned storage region **304**, of the executed threads exceeds the maximum number, stored in the storage region **307**, of threads assignable to one user, the thread assignment controller **102** does not activate a server thread **106** based on the received request. In this case, the request receiver **101** keeps the request waiting in the request queue secured on the memory of the server machine **100**. This control operation may inhibit a user who processes a large amount of data from taking a resource away from a user who processes a small amount of data. Thus, the control operation may achieve access that is fair between users.

On the other hand, if the number, stored in the aforementioned storage region **304**, of the executed threads does not exceed the maximum number, stored in the storage region **307**, of threads assignable to one user, the thread assignment controller **102** executes the following control.

The thread assignment controller **102** controls the assignment of threads so as to ensure that the number, stored in the storage region **305**, of executed threads for all the users does not exceeds the number, stored in a storage region **308** on the memory of the server machine **100**, of times of concurrently executable access (**306** in FIG. **3**).

When receiving a request from the request receiver **101**, the thread assignment controller **102** activates a server thread **106** based on the received request if the number, stored in the storage region **305**, of executed threads for all the users does not exceed the number, stored in the storage region **308**, of times of concurrently executable access.

If the number of the executed threads for all the users exceeds the number of times of concurrently executable access, the thread assignment controller **102** executes the following control operation.

The thread assignment controller **102** references the hash table **303**, acquires the minimum number of executed threads among the numbers, stored in the storage regions **304** for the users, of executed threads, and resets the acquired number as the maximum number, stored in the storage region **307**, of threads assignable to one user.

As a result, regarding a user ID for which the number of executed threads is large, the issuance of a request to a server thread **106** is suppressed so as to ensure that the number of the executed threads is equal to or smaller than the aforementioned reset maximum number of threads assignable to one user. Specifically, based on a user for which a counted number of executed threads is smallest among the numbers (numbers of times of concurrently executed threads), counted for the users, of executed threads, the numbers of server threads **106** executed based on requests from the other users are reduced.

In this manner, the number (number of concurrently executed threads) of executed threads may be controlled so as to ensure that a request provided by a user who accesses a large amount of data to be input and output does not significantly delay a request provided by a user who accesses a small amount of data to be input and output. As a result, access fairness between users may be secured.

Next, a detailed control operation of the distributed file system with the configuration illustrated in FIG. **1** according to the first embodiment is described.

First, a detailed operation of the request transmitter **111** included in the client machine **110** is described below.

FIG. **4** is a diagram describing the request transmitter **111** included in the client machine **110** illustrated in FIG. **1**.

When users perform access **401**A, **401**B, and the like to the distributed file system, the request transmitter **111** generates requests **402**A, **402**B, and the like and transmits the requests **402**A, **4026**, and the like to the server machine **100** illustrated in FIG. **1**.

The request transmitter **111** adds, to the requests **402**A, **402**B, and the like, information (user IDs) identifying the users who perform the access **401**A, **401**B, and the like.

Thus, the request receiver **101** of the server machine **100** may identify the users based on the requests.

As described above with reference to FIG. **3**, the thread assignment controller **102** may control, based on the user IDs, the number (number of concurrently executed threads) of executed threads for each of the users and the number (number of concurrently executed threads) of executed threads for all the users upon the activation of a server thread **106**.

FIG. **5** is a diagram illustrating a specific example of data formats of the requests **402**A, **402**B, and the like illustrated in FIG. **4**. A value that indicates a request type such as write (indicating a write request) or read (indicating a read request) is stored at a position corresponding to a data offset **0** of the request, for example. A user ID such as "5300" is stored at a position corresponding to a data offset **8** of the request, for example. A size that indicates the length of data to be written is stored at a position corresponding to a data offset **16** of the request. If the request type indicates write, the data to be written in the disk device **120** (refer to FIG. **1**) is stored at a position corresponding to a data offset **24** of the request.

Next, detailed operations of the request receiver **101** included in the server machine **100** are described.

Data sizes (for example, the sizes of data requested to be written) of requests transmitted from the client machine **110** may be different. Thus, if writing of data in the disk device **120** is executed, processing times may vary and the load state of the disk device **120** may not be accurately calculated. Even if the data sizes of the requests transmitted from the client machine **110** are different, the request receiver **101** divides a data size of each of the requests received from the client machine **110** into certain sizes causing each of time periods for access to be a certain time period or less. The divided data sizes may be equal to the block size (a multiple of 4 KB (kilobytes) in general) of the file system of the disk device **120**, for example.

It is apparent from measured values that times for processing executed for the access to the disk device **120** are not significantly different when the divided data sizes are equal to or smaller than the block size. FIG. **6** is a diagram illustrating an example of a graph of time periods (of seconds) for writing data with respect to the sizes of the data to be written if the disk device **120** has a third extended (EXT3) file system (block size=4 KB).

As is understood from the example of the graph, the times for writing the data having the sizes equal to or smaller than the block size (of 4 KB) in the disk device **120** are not significantly different. Thus, the request receiver **101** divides a data size of a request from the client machine **110** into the same sizes as the block size and causes data items each having the same size as the block size to be written in the disk device **120** without writing the data with the size (refer to FIG. **4**) specified by a user. Thus, time periods for processing executed upon disk access may be a fixed time period, and the load state of the disk device **120** may be accurately calculated.

In order to divide a data size of a request from the client machine **110** into the same sizes as the block size and process data, the request receiver **101** manages requests using a data structure illustrated in FIG. **7**.

Referring to FIG. **7**, every time the request receiver **101** receives a request from the request transmitter **111** included in the client machine **110** operated by the user, the request receiver **101** executes the following control operation. The request receiver **101** divides a data size of the received request into certain sizes equal to, for example, the block size of 4 KB and causes data items each having the certain size to be stored (queued) in a request queue **305** (**305**A, **305**B, or the like) secured as a storage region for the user on the memory included in the server machine **100**.

More specifically, the request receiver **101** executes a process **702** of generating a hash value for a user ID **701** added to the received request. For example, the hash value "1" is generated for the user ID "**5300**" (refer to **402**A of FIG. **4**) added to the received request A.

The request receiver **101** searches a record having the generated hash value in an INDEX item on a hash table **703** (different from the hash table **303** illustrated in FIG. **3**) stored on the memory of the server machine **100**.

If the interested record does not exist on the hash table **703**, the request receiver **101** executes the following process. First, the request receiver **101** generates a new record on the hash table **703** and registers the hash value in an INDEX item of the new record. In addition, the request receiver **101** secures a request queue **704** (**704**A, **704**B, or the like) for storing requests representing, for example, the same data sizes as the block size and obtained by dividing the request corresponding to the user ID from which the hash value has been generated. Then, the request receiver **101** registers a top address of the generated request queue **704** in an address item of the record newly generated on the hash table **703**. Then, the request receiver **101** acquires the top address. For example, a request queue **704**A is secured for the hash value "1" generated from the user ID "5300" indicated by the request **402**A illustrated in FIG. **4**. Then, the hash value "1" and the top address "0x70680000" of the request queue **704**A are registered in the new record on the hash table **703**. Alternatively, for example, a request queue **704**B is secured for a hash value "3" generated from a user ID "5400" indicated by a request queue **704**B illustrated in FIG. **4**. Then, the hash value "3" and a top address "0x70665000" of the request queue **704**B are registered in a new record on the hash table **703**.

When finding the record having the hash value in the INDEX item on the hash table **703**, the request receiver **101** acquires the top address registered in the found record.

The request receiver **101** generates one or more requests obtained by dividing the data size of the received request into the certain sizes such as the same sizes as the block size of 4 KB and registers the generated requests at the end of the request queue **704** indicated by the top address acquired from the hash table **703** on the memory. For example, requests **705**A-**1** (having a data length of 4 KB), **705**A-**2** (having a data length of 4 KB), and **705**A-**3** (having a data length of 2 KB) are generated by dividing the data (illustrated in FIG. **4**) having a data length of 10 KB and to be written. Then, the requests **705**A-**1**, **705**A-**2**, and **705**A-**3** are associated with the user ID added to the request **402**A and sequentially registered in the request queue **704**A to be accessed through the hash table **703**. Alternatively, for example, requests **705**B-**1** (having a data length of 4 KB) and **705**B-**2** (having a data length of 1 KB) are generated by dividing the data (illustrated in FIG. **4**) having a data length of 5 KB and to be written. Then, the requests **705**B-**1** and **705**B-**2** are associated with the user ID added to the request **402**B and sequentially registered in the request queue **704**B to be accessed through the hash table **703**.

The data size (data length) of the last request **705**A-**3** registered in the request queue **704**A and the data size (data length) of the last request **705**B-**2** registered in the request queue **704**B are not equal to the block size of 4 KB and are fractions. As described above with reference to FIG. **6**, however, time periods for processing of the requests are each a certain time period that is nearly equal to a period of time for processing of a request having a data size of 4 KB. In the first embodiment, time periods for disk access executed based on requests are equal to the certain time period, and thus the load state of the disk device **120** may be accurately calculated.

As described above, since the request queues **704** (**704**A, **704**B, and the like) are managed by the request receiver **101**, the thread assignment controller **102** may access the disk device **120** on a user basis and a block size basis as described later.

Next, detailed operations of the thread assignment controller **102** included in the server machine **100** are described.

FIG. **8** is a diagram illustrating an example of a data configuration of a hash table **803** stored on the memory of the server machine **100** by the thread assignment controller **102**. The hash table **803** has the same function as the hash table **303** described with reference to FIG. **3**. However, the storage regions **304** described with reference to FIG. **3** and storing the numbers of threads executed for the user IDs are directly stored as one item in the hash table **803** and the pointer value item is omitted in FIG. **8**. In addition, the storage region **305** described with reference to FIG. **3** and storing the number of threads executed for all the users is stored at the end of the hash table **803** as illustrated in FIG. **8**. In addition, an INDEX item for storing hash values, and the user IDs from which the hash values are generated, are stored in records included in the hash table **803**.

The thread assignment controller **102** assigns server threads **106** (FIG. **1**) to requests received from the request receiver **101** for the user IDs and representing, for example, the same data sizes as the block size of 4 KB on a user basis using a round-robin method. The thread assignment controller **102** manages the number (number of assigned threads) of executed threads on the hash table **803** for each user and controls the numbers of executed threads so as to inhibit the numbers of the executed threads from exceeding the number of times of concurrently executable access to the disk device **120** due to the assignment of a server thread **106**.

FIG. **9** is a flowchart of an example of a process of controlling the assignment of threads. At least one central processing unit (CPU) of the server machine **100** reads, into the memory, a thread assignment control program stored in an external storage device or the like and executes the process of controlling the assignment of threads. In the process of controlling the assignment of threads, the CPU of the server machine **100** executes a function of the thread assignment controller **102**. In addition, the process is executed as a main process of the distributed file system on the server machine **100**. The single CPU may include multiple cores.

First, a variable Ta on the memory is initialized to 999999, a variable Umax is initialized to a value Ta, and a variable Count is initialized to 0 (in step S**901**). The variable Ta corresponds to the storage region **308** illustrated in FIG. **3** and holds the number of times of concurrently executable access. The variable Umax corresponds to the storage region **307** illustrated in FIG. **3** and holds the maximum number of threads assignable to one user. The variable Count is a variable that controls a time interval at which a process of calculating the number of times of concurrently executable access in step S**909** (described later) is executed. The process of calculating the number of times of concurrently executable access is a function of the disk load state analyzer **104** illustrated in FIG. **1**. After the value of the variable Count is initialized and set to 0 in step S**901**, the value of the variable Count is incremented by 1 in step S**907** every time access executed based on a single request is completed. Then, if it is determined that the value of the variable Count reaches **1000** in step S**908**, the process of calculating the number of times of concurrently executable access is executed in step S**909**. After that, the value of the variable Count is reset to 0 in step S**910**. Then, the same process is repeated.

Next, a top request registered in any of the request queues **704** (**704**A, **704**B, . . .) generated on the memory by the request receiver **101** and provided for the users is referenced using the round-robin method or the like, for example (in step S**902**).

Next, the hash table **803** generated on the memory is referenced, and the number of executed threads for a user ID corresponding to the request queue **704** referenced in step S**902** is acquired (in step S**903**). Then, it is determined whether or not the number of executed threads is smaller than the maximum number, held by the variable Umax, of threads assignable to one user (in step S**903**).

If the answer to the determination of step S**903** is YES, it is determined whether or not the number, stored in the storage region at the end of the hash table **803**, of executed threads for all the users is smaller than the number, held by the variable Ta, of times of concurrently executable access (in step S**904**).

If the answer to the determination of step S**904** is YES, a server thread **106** (FIG. **1**) is assigned to the request referenced in step S**902** and corresponding to the user ID (in step S**905**). After that, the number, corresponding to the user ID on the hash table **803**, of executed threads is incremented by 1 (in step S**905**). Concurrently, the number, stored at the end of the hash table **803**, of executed threads for all the users is incremented by 1 (in step S**905**).

After that, a disk access process is executed by the server thread **106** assigned to the request referenced in step S**902** in step S**905** and corresponding to the user ID (in step S**906**). In the disk access process, a function of the disk access time recorder **103** illustrated in FIG. **1** is executed. Details of the disk access process are described with reference to FIGS. **9** to **11**.

When the disk access process executed on the aforementioned request is completed, the number of executed threads that is registered in the record corresponding to the user ID indicated on the hash table **803** and subjected to the disk access process is reduced by 1 (in step S**907**). Concurrently, the number of executed threads for all the users that is stored at the end of the hash table **803** is reduced by 1 (in step S**907**). In addition, the variable Count is incremented by 1 (in step S**907**).

After that, it is determined whether or not the value of the variable Count reaches **1000** (in step S**908**).

If the answer to the determination of step S**908** is NO, the process returns to step S**902** and is executed on the next request.

While the process is repeatedly executed on each request, the value of the variable Count is incremented in step S**907**. When the value of the variable Count reaches **1000**, the answer to the determination of step S**908** is YES.

As a result, the process of calculating the number of times of concurrently executable access is executed (in step S**909**). In this process, the function of the disk load state analyzer **104** illustrated in FIG. **1** is executed. Details of the process are described with reference to FIG. **12** and FIGS. **13**A to **13**C. As a result of the process, the number, held by the variable Ta, of times of concurrently executable access is updated. The value of the variable Ta is set to a large value in step S**901** immediately after the activation of the system and the variable Ta becomes in a state in which server threads **106** are assignable to requests without being limited. However, when a time elapses and the number of times of access executed in concurrent increases, the process of calculating the number of times of concurrently executable access in step **S909** limits the number, held by the variable Ta, of times of concurrently executable access to an appropriate value based on the current load state of the disk device **120** or to "3" or the like.

When the number of times of concurrently executable access is calculated, the value of the variable Count is reset to 0, and the number, newly held by the variable Ta in step **S909**, of times of concurrently executable access is set as the maximum number, held by the variable Umax, of threads assignable to one user. Specifically, immediately after the number of times of concurrently executable access is updated, server threads **106** of which the number is equal to or smaller than the number of times of concurrently executable access may be assigned fairly for the users.

After that, the process returns to step **S902** and is executed on the next request.

In the aforementioned process, when the number of executed threads for the user ID corresponding to the request queue referenced in step **S902** reaches the maximum number, held by the variable Umax, of threads assignable to one user or the answer to the determination of step **S903** is NO, a server thread **106** is not activated. In this case, the aforementioned request is kept waiting in the request queue **704**. After that, the process returns to step **S902** and is executed on a request corresponding to the next user ID. The operation of limiting the number of executed threads for each user based on the variable Umax may inhibit a user who processes a large amount of data from taking a resource away from a user who processes a small amount of data. Thus, access that is fair between the users is achieved even if the number of executed threads for all the users does not exceed a predetermined number (for example, Ta).

In the aforementioned process, when the number of executed threads for all the users reaches the number, held by the variable Ta, of times of concurrently executable access or the answer to the determination of step **S904** is NO, the following control operation is executed. The hash value **803** is referenced, the minimum number of executed threads among the numbers of executed threads for the user IDs is acquired, and the acquired number is reset as the maximum, held by the variable Umax, of threads assignable to one user (in step **S911**). As a result, in step **S903**, regarding a user ID for which the number of executed threads is large, the activation of a server thread **106** based on a request is suppressed so as to ensure that the number of the executed threads is smaller than the reset value of the variable Umax. Specifically, based on a user for which the number of executed threads is smallest among the numbers, calculated for the users, of executed threads, the number of server threads **106** executed based on a request from another user is reduced. The process of step **S911** increases a possibility that a request from a user who accesses a relatively small amount of data to be input and output is processed. Thus, access that is fair between users is achieved by the process of step **S911** even if the number of executed threads for all the users exceeds the predetermined number (for example, Ta).

In this manner, the number (number of times of concurrently executed threads) of executed threads may be controlled by the control operation exemplified in FIG. **3** so as to ensure that a delay, caused by a request provided by a user who accesses a large amount of data to be input and output, of a request provided by a user who accesses a relatively small amount of data to be input and output is avoided. As a result, access that is fair between users may be secured.

In step **S911**, the value of the variable Umax may not be set to a value corresponding to a user ID for which the number of executed threads is smallest. In step **S911**, the value of the variable Umax may be controlled and set to a value smaller than the current value of the variable Umax.

Next, detailed operations of the disk access time recorder **103** illustrated in FIG. **1** are described.

As described above, the disk access time recorder **103** records, in an aggregation table **1** exemplified in FIG. **10**, start times (disk access start times **1001**) of access to the disk devices **120** and end times (disk access end times **1002**) of the access to the disk devices **120**, for example. Then, the disk access time recorder **103** calculates, from the recorded start and end times of the access, elapsed time periods **1003** and the numbers **1004** of times of access executed in concurrent and stores the calculated elapsed time periods **1003** and the calculated numbers **1004** in the aggregation table **1**.

FIG. **11** is a flowchart of a detailed example of the disk access process of step **S906** illustrated in FIG. **9**. In the disk access process, a function of the disk access time recorder **103** is executed and controls the aggregation table **1** having an exemplary data configuration illustrated in FIG. **10**.

When step **S906** illustrated in FIG. **9** is called, a new record is generated in the aggregation table **1**. Then, a current time is written in an item included in the new record and representing a disk access start time **1001** (in step S**1101**).

Next, the disk access process is executed by the server thread **106** assigned in step **S905** illustrated in FIG. **9** (in step S**1102**).

When the disk access process of step S**1102** is completed, a current time is written in an item representing a disk access end time **1002** and included in the new record generated in the aggregation table **1** in step S**1101** (in step S**1103**). In addition, a value of the item included in the record and representing the disk access start time **1001** is subtracted from a value of the item included in the record and representing the disk access end time **1002**, and the result of the subtraction is written in an item included in the same record and representing an elapsed time period **1003** (in step S**1103**).

After that, a process of calculating the number of times of access executed in concurrent is executed (in step S**1104**). An example of this calculation process is illustrated as a flowchart in FIG. **12**.

Referring to FIG. **12**, first, a time value of 10 milliseconds is set to a variable Li stored on the memory of the server machine **100** as a unit for checking (in step S**1201**). In addition, the value, set in step S**1101** illustrated in FIG. **11**, of the item included in the record on the aggregation table **1** and representing the disk access start time **1001** is initially set to the variable Ts stored on the memory (in step S**1201**). Similarly, the value, set in step S**1103** illustrated in FIG. **11**, of the item included in the record on the aggregation table **1** and representing the disk access end time **1002** is initially set to the variable Te stored on the memory (in step S**1201**). In addition, an initial value of 0 is set to a variable Total stored on the memory and representing the total of the numbers of times of access executed in concurrent (in step S**1201**). Furthermore, an initial value of 0 is set to a variable Cnt stored on the memory and provided to count the number of time intervals of, for example, 10 milliseconds (in step S**1201**).

Next, processes of steps S1202 and S1203 are executed at each of the time intervals of, for example, 10 milliseconds.

First, time periods from disk access start times **1001** to disk access end times **1002** in records of the aggregation table **1** having the exemplary data configuration illustrated in FIG. **10** are referenced (in step S**1202**). Then, the number of times of concurrently executed disk access is counted by counting the number of time periods that are among the time periods in the records and each include a time interval of, for example, 10 milliseconds and are from the time value of the variable Ts to a time value calculated by adding the time value of the variable Ts to the time value of the variable Li (in step S**1202**). Then, the counted number of the times of the concurrently executed disk access is added to the variable Total (in step S**1202**). In this process, the number of times of access executed in concurrent in a time period of, for example, 10 milliseconds from the time value of the variable Ts to the calculated time value is counted by adding the time value of the variable Ts to the time value of the variable Li.

After that, the variable Cnt is incremented by 1, the time value of the variable Li is added to the time value of the variable Ts, and the new time value of the variable Ts is obtained (in step S**1203**). The new time value of the variable Ts indicates a start time of the next time period of, for example, 10 milliseconds.

After that, it is determined whether or not the time value of the variable Ts reaches a value of the item storing the disk access end time **1002** indicated by the variable Te (in step S**1204**).

If the answer to the determination of step S**1204** is NO, the process returns to step S**1202**, and the process of counting the number of times of access executed in concurrent in the next time period of, for example, 10 milliseconds is repeated.

If the answer to the determination of step S**1204** is YES, the total, held by the variable Total, of all the numbers of times of access executed in concurrent for the time periods of, for example, 10 milliseconds is divided by the number, held by the variable Cnt, of the time periods of, for example, 10 milliseconds and the result of the division is rounded off to the closest natural number (in step S**1205**). Then, the result of the calculation is written in an item that is included in the record generated in step S**1101** illustrated in FIG. **9** on the aggregation data **1** having the exemplary data configuration illustrated in FIG. **10** and represents the number **1004** of times of access executed in concurrent.

After that, the process depicted in the flowchart of FIG. **12** is terminated and the process of calculating the number of times of access executed in concurrent in step S**1104** illustrated in FIG. **11** is terminated. As a result, the disk access process depicted in the flowchart of FIG. **11** is terminated and the disk access process of step **S906** illustrated in FIG. **9** is terminated.

In this manner, the function of the disk access time recorder **103** illustrated in FIG. **1** is achieved.

Data aggregated by the aforementioned disk access process into the aggregation table having the exemplary data configuration illustrated in FIG. **10** is obtained by the same calculation as the Equations (1) described with reference to FIG. **2**. However, an average of aggregated numbers of times of access executed in concurrent is rounded off to the closest natural number in each record (indicating each access) of the aggregation table **1** in order to simplify the process of calculating the number of times of concurrently executable access using an aggregation table **2** (described later).

Next, detailed operations of the disk load state analyzer **104** illustrated in FIG. **1** are described.

An average of elapsed time periods is calculated from the aggregation table **1** having the exemplary data configuration illustrated in FIG. **10** for each of the numbers of times of access executed in concurrent, and the aggregation table **2** having an exemplary data configuration illustrated in FIG. **13**A is generated and stored on the memory of the server machine **100**.

The aggregation table **1** illustrated in FIG. **10** has only one record that has an item storing **1** and representing the number **1004** of times of access executed in concurrent. First, **1** is written in an item that represents the number **1301** of times of access executed in concurrent and is included in a record newly generated on the aggregation table **2** illustrated in FIG. **13**A. Subsequently, a value of an item representing an elapsed time period **1003** and included in the record having the item storing **1** and representing the number **1004** of times of access executed in concurrent on the aggregation table **1** (illustrated in FIG. **10**), or 0.021219, is written in an item representing an elapsed time period **1302** and included in the record having the item that stores **1** and represents the number **1301** of times of access executed in concurrent on the aggregation table **2** illustrated in FIG. **13**A.

The aggregation table **1** illustrated in FIG. **10** has top two records that each have an item storing **2** and representing the number **1004** of times of access executed in concurrent. First, **2** is written in an item that represents the number **1301** of times of access executed in concurrent and is included in a record newly generated on the aggregation table **2** illustrated in FIG. **13**A. Subsequently, an average of 0.030298 and 0.025819 that are values of items representing the elapsed time periods **1003** and included in the two records having the items representing the numbers **1004** of times of access executed in concurrent on the aggregation table **1** illustrated in FIG. **10** is calculated to be 0.0280585. Then, the average value of 0.0280585 is written in an item representing an average **1302** of elapsed time periods and included in the record that has the item storing **2** and representing the number **1301** of times of access executed in concurrent on the aggregation table **2** (illustrated in FIG. **13**A). In addition, a value of 1.32, which is obtained by dividing the average value of 0.0280585 by the value of 0.021219 stored in the item representing the average **1302** of elapsed time periods and included in the record having the item storing **1** and representing the number **1301** of times of access executed in concurrent on the aggregation table **2**, is written in an item representing a ratio **1303** of averages of elapsed time periods and included in the record having the item storing **2** and representing the number **1301** of times of access executed in concurrent on the aggregation table **2**. The value of 1.32 indicates the ratio of the average **1302** of elapsed time periods in which the number of times of access executed in concurrent is 2 to the average **1302** of elapsed time periods in which the number of times of access executed in concurrent is **1**.

In addition, the aggregation table **1** illustrated in FIG. **10** has the last three records that each have an item storing **3** and representing the number **1004** of times of access executed in concurrent. First, **3** is written in an item that represents the number **1301** of times of access executed in concurrent and is included in a record newly generated on the aggregation table **2** illustrated in FIG. **13**A. Subsequently, an average of 0.058311, 0.060431, and 0.063521 that are values of items representing the elapsed time periods **1003** and included in the three records having the items representing the numbers

1004 of times of access executed in concurrent on the aggregation table 1 illustrated in FIG. 10 is calculated to be 0.0607543. Then, the average value of 0.0607543 is written in an item representing the average 1302 of elapsed time periods and included in the record having the item that stores 3 and represents the number 1301 of times of access executed in concurrent on the aggregation table 2 illustrated in FIG. 13A. In addition, a value of 2.86, which is obtained by dividing the average value of 0.0607543 by the value of 0.021219 stored in the item representing the average 1302 of elapsed time periods and included in the record having the item storing 1 and representing the number 1301 of times of access executed in concurrent on the aggregation table 2, is written in an item representing a ratio 1303 of averages of elapsed time periods and included in the record having the item storing 3 and representing the number 1301 of times of access executed in concurrent on the aggregation table 2. The value of 2.86 indicates the ratio of the average 1302 of elapsed time periods in which the number of times of access executed in concurrent is 3 to the average 1302 of elapsed time periods in which the number of times of access executed in concurrent is 1.

In order to suppress, to N times such as two times, a reduction in a time for a response when a high load is applied to the disk device 120, the following control may be executed. That is, the number of times of concurrent access to the disk device 120 is controlled and set to a certain number so as to ensure that an elapsed time period in which the concurrent access is executed is equal to or shorter than N times (such as two times) of an elapsed time period in which the number of times of access executed in concurrent is 1. Referring to the item representing ratios 1303 of averages of elapsed time periods on the aggregation table 2 illustrated in FIG. 13, the value of the item representing the ratio 1303 and corresponding to the item storing 2 and representing the number 1301 of times of access executed in concurrent is smaller than 2 times (or is 1.32 times), while the value of the item representing the ratio 1303 and corresponding to the item storing 3 and representing the number 1301 of times of access executed in concurrent is larger than 2 times (or is 2.86 times). Thus, in the example of the aggregation table 2 illustrated in FIG. 13A, the value of the item that represents the number 1302 of times of access executed in concurrent and suppressing a reduction in a response time is 2 and determined to be the number of times of concurrently executable access.

An average 1302 of elapsed time periods may not be obtained for a value of an item representing the number 1301 of times of access executed in concurrent, depending on an access pattern of a user. For example, in the aggregation table 2 illustrated in FIG. 13B, averages 1302 of elapsed time periods that are represented by items corresponding to items storing 2 and 3 and representing the numbers 1301 of times of access executed in concurrent are not obtained and are 0, and values of items representing ratios 1303 of averages of elapsed time periods and corresponding to the items representing the averages 1302 are not calculated. The ratios are calculated based on linear interpolation using a combination of the value of the item storing 1 and representing the number 1301 of times of access executed in concurrent and the value of the item storing 0.021219 and representing the average 1302 of elapsed time periods and a combination of the value of the item storing 4 and representing the number 1301 of times of access executed in concurrent and the value of the item storing 0.0802534 and representing the average of elapsed time periods.

The ratio of the average of the elapsed time periods in which the number of times of access executed in concurrent is 2=(3.78 times−1 time)/3 ×1+1 time=1.92 times

The ratio of the average of the elapsed time periods in which the number of times of access executed in concurrent is 3=(3.78 times−1 time)/3 ×2+1 time=2.85 times

If a value of an item representing the average 1302 of elapsed time periods and corresponding to an item storing 1 and representing the number 1301 of times of access executed in concurrent does not exist, a standard elapsed time period is not clear. In this case, the number of times of concurrently executable access may be controlled so as not to be changed until data when the number of times of access executed in concurrent is 1 is obtained.

For example, if the number of times of concurrently executable access is changed to 2, disk access is executed after the change in the number of times of concurrently executable access, and the aggregation table 2 is generated, only values of items representing averages 1302 of elapsed time periods and corresponding to items storing 1 and 2 and representing the numbers 1301 of times of access executed in concurrent are obtained as exemplified in FIG. 13C. This is due to the fact that the assignment of server threads 106 is controlled by the thread assignment controller 102 so as to ensure that the number of times of access executed in concurrent does not exceed 2.

In such a case, when the number of times of access executed in parallel is 3 or more, an elapsed time period is not clear. Thus, the linear interpolation is executed, and the elapsed time period in which the number of times of access executed in parallel is 3 or more is compared with the elapsed time period in which the number of times of access executed in parallel is 1. Then, values of items representing averages 1302 of elapsed time periods in which the numbers of times of access executed in parallel exceed the N times such as 2 times are calculated according to the following equations.

The ratio of the average of the elapsed time periods in which the number of times of access executed in parallel is 3=(1.32 times−1 time)/1×2+1 time=1.64 times

The ratio of the average of the elapsed time periods in which the number of times of access executed in parallel is 4=(1.32 times−1 time)/1×3+1 time=1.96 times

As described above, the amount of an increase in the number of times of concurrently executable access may be determined by the execution of the linear interpolation on the number, exceeding the number of times of concurrently executable access, of times of access executed in parallel when the number of times of concurrently executable access is too small (or excessively reduced or when there is a margin for a process of the disk device 120).

FIG. 14 is a flowchart of a detailed example of the process of calculating the number of times of concurrently executable access in step S909 illustrated in FIG. 9. In this process, a function of the disk load state analyzer 104 is executed and controls the aggregation table 2 having the exemplary data configuration illustrated in FIG. 13A.

First, the maximum value among values of items representing the numbers 1004, aggregated into the aggregation table 1 exemplified in FIG. 10, of times of access executed in parallel is set to a variable Mx stored on the memory of the server machine 100 (in step S1401). In addition, 1 is set to a variable He that indicates a value of an item representing the number 1301 of times of access executed in parallel upon the execution of the aggregation into the aggregation table 2 (in step S1401).

Next, values of items, which represent elapsed time periods **1003** and are included in records having items representing the numbers **1004**, equal to the variable He, of times of access executed in parallel among values of items representing the numbers **1004** of times of access executed in parallel on the aggregation table **1** illustrated in FIG. **10**, are aggregated (in step S**1402**). If the variable He is 1, 0.021219 that is the value of the item representing the elapsed time period **1003** and included in the record having the item representing the number **1004** of times of access executed in parallel and storing **1** on the aggregation table **1** illustrated in FIG. **10** is obtained as an aggregated value. If the variable He is 2, 0.030298 and 0.025819 that are the values of the items representing elapsed time periods **1003** and included in the two records having the items representing the numbers **1004** of times of access executed in parallel and storing **2** on the aggregation table **1** illustrated in FIG. **10** are aggregated, and the aggregated value of 0.056117 is obtained. If the variable He is **3**, 0.058311, 0.060431, and 0.063521 that are the values of the items representing the elapsed time periods **1003** and included in the three records having the items representing the numbers **1004** of times of access executed in parallel and storing **3** on the aggregation table **1** illustrated in FIG. **10** are aggregated, and the aggregated value of 0.182263 is obtained.

Next, it is determined whether or not the aggregated elapsed time period is 0 (or whether or not data corresponding to the value of the variable He is absent) (in step S**1403**).

If the total of the aggregated elapsed time periods is not 0 or the answer to the determination of step S**1403** is NO, the total of the elapsed time periods aggregated in step S**1402** is divided by the number of the items representing the aggregated elapsed time periods and an average of the aggregated elapsed time periods is calculated (in step S**1404**). If the variable He is 1, the aggregated value of 0.021219 is divided by 1 or the number of the items representing the aggregated elapsed time periods and the average is calculated to be 0.021219. If the variable He is 2, the aggregated value of 0.056117 is divided by 2 or the number of the items representing the aggregated elapsed time periods, and the average of the aggregated elapsed time periods is calculated to be 0.0280585. If the variable He is 3, the aggregated value of 0.182263 is divided by 3 or the number of the items representing the aggregated elapsed time periods and the average of the elapsed time periods is calculated to be 0.0607543. Then, the numbers, indicated by the variable He, of times of access executed in parallel are written as the values of the items representing the numbers **1301** of times of access executed in parallel in the records of the aggregation table **2** exemplified in FIG. **13**A, and the aforementioned averages are written as the values of the items representing the averages **1302** of the elapsed time periods in the records of the aggregation table **2** exemplified in FIG. **13**A (in step S**1404**). In addition, values obtained by dividing the values of the items representing the averages **1302** of the elapsed time periods and included in the records by the value of the item representing the average **1302** of the elapsed time periods and corresponding to the record having the item storing **1** and representing the number **1301** of times of access executed in parallel are written as the values of the items included in the records and representing the ratios **1303** of the averages of the elapsed time periods (in step S**1404**). In the aforementioned calculation example, 1 is written as the number of times of access executed in parallel, 0.021219 is written as the average of the elapsed time periods, and 1 is written as the ratio of the averages of the elapsed time periods in the aggregation table **2**. In addition, 2 is written as the number of times of access executed in parallel, 0.0280585 is written as the average of the elapsed time periods, and 1.32 is written as the ratio of the averages of the elapsed time periods in the aggregation table **2**. Furthermore, 3 is written as the number of times of access executed in parallel, 0.0607543 is written as the average of the elapsed time periods, and 2.86 is written as the ratio of the averages of the elapsed time periods in the aggregation table **2**.

After that, 1 is added to the variable He (in step S**1405**).

Then, it is determined whether or not the value of the variable He reaches the value of the variable Mx indicating the maximum value among the values of the items included in the aggregation table **1** and representing the numbers **1004** of times of access executed in parallel (in step S**1406**).

If the answer to the determination of step S**1406** is NO, the process returns to step S**1402** and the aggregation process is repeatedly executed on the number, represented by the variable He after the addition of 1, of times of access executed in parallel.

In the repeated processes of steps S**1402** to S**1406**, if the total of the elapsed time periods aggregated in step S**1402** is 0 or a value, corresponding to the value of the variable He, of an item representing the number **1004** of times of access executed in parallel does not exist on the aggregation table **1**, the answer to the determination of step S**1403** is YES. In this case, it is determined whether or not the value of the variable He is 1 (in step S**1409**).

If the value of the variable He is not 1 or the answer to the determination of step S**1409** is NO, the aggregation of elapsed time periods in which the number of times of access executed in parallel is equal to the value of the variable He is ignored, the process proceeds to step S**1405**, and the aggregation process is executed on the number, indicated by the value of the variable He after the addition of 1, of times of access executed in parallel.

If the value of the variable He is 1 or the answer to the determination of step S**1409** is YES, a value of an item representing an elapsed time period **1003** and corresponding to 1 that is the number of times of access executed in parallel and is a standard for the calculation of the number of times of concurrently executable access is not obtained from the aggregation table **1**. In this case, the process depicted in the flowchart of FIG. **14** is terminated, the process of calculating the number of times of concurrently executable access in step S**909** illustrated in FIG. **9** is terminated, data when the number of times of access executed in parallel is 1 is obtained, and thus the number of times of concurrently executable access is controlled so as not to be changed.

If the answer to the determination of step S**1406** is YES and the aggregation executed based on the aggregation table **1** and reflected in the aggregation table **2** is terminated, an average **1302** of elapsed time periods is calculated for the number, causing the answer to the determination of step S**1403** to be YES, of times of access executed in parallel as described with reference to FIGS. **13**B and **13**C (in step S**1407**). After that, the items representing the ratios **1303** of the averages of the elapsed time periods and included in the records of the aggregation table **2** are referenced, and thus the maximum value among values of items representing the numbers **1301** of times of access executed in parallel and included in records indicating that the ratios are equal to or smaller than N times is calculated. Then, the maximum value is set to a variable Ta as the number of times of concurrently executable access (in step S**1407**).

Lastly, details of the aggregation table **1** exemplified in FIG. **10** and details of the aggregation table **2** exemplified in

FIG. **13** are cleared (in step S**1408**), the process depicted in the flowchart of FIG. **14** is terminated, and the process of calculating the number of times of concurrently executable access in step S**909** illustrated in FIG. **9** is terminated.

As described above, if a part of data of the numbers of times of access executed in parallel does not exist, a value is calculated using linear interpolation, and the optimal number of times of concurrently executable access may not be obtained. In addition, an appropriate number of times of concurrently executable access may change depending on an access pattern (random access, sequential access, or the like) of a user and a variation (a temporal reduction caused by a failure of a part of the disks forming the RAID system) in performance of the disks. Thus, the determined number of times of concurrently executable access is periodically checked. A process of checking the number of times of concurrently executable access is executed using the variable Count used in the flowchart of FIG. **9**. When the variable Count reaches **1000** in step S**908** included in the process depicted in the flowchart of FIG. **9**, the process of calculating the number of times of concurrently executable access is executed in step S**909**. By changing the value of 1000, a frequency at which the number of times of concurrently executable access is checked is adjusted.

The thread assignment controller **102** described with reference to FIG. **8** may execute control so as to assign a large number of threads to a prioritized user on a priority basis without fairly treating all the users. By executing the control, a system administrator (root user or the like) may be prioritized over general users.

Specifically, in a process of suppressing an upper limit on the number of executed threads for each of the users, the control is executed so as to ensure that an upper limit on the number of executed threads for the prioritized user is not suppressed. However, if the number of times of access to be executed in parallel exceeds the number of times of concurrently executable access for all the users, the control may be executed so as to suppress the upper limit on the number of executed threads for the prioritized user in order to suppress a delay of a process of the disk device **120** for the prioritized user.

FIG. **15** is a diagram illustrating an example of a data configuration of a hash table **1501** stored on the memory of the server machine **100** by the thread assignment controller **102** illustrated in FIG. **1** as the second embodiment in which an operation of executing the aforementioned control on the prioritized user is achieved. The hash table **1501** is formed by adding a user type item (highlighted in gray) to the aforementioned hash table **803** illustrated in FIG. **8**. As values of the user type item, "general" and "priority" are set, for example.

FIG. **16** is a flowchart of an example of a process of controlling the assignment of the threads according to the second embodiment in which the operation of executing the control on the prioritized user is achieved. In FIG. **16**, steps of executing the same processes as the aforementioned flowchart of FIG. **9** are indicated by the same reference numbers as the flowchart of FIG. **9**. A difference between the process depicted in the flowchart of FIG. **16** and the process depicted in the flowchart of FIG. **9** is a control process to be executed if the answer to the determination of step S**903** is NO.

Referring to FIG. **16**, if the number of executed threads for the user ID corresponding to the request queue **703** referenced in step S**902** reaches the maximum number, held by the variable Umax, of threads assignable to one user or the answer to the determination of step S**903** is NO, step S**1601** is executed. In step S**1601**, a value of a user type item corresponding to the user ID currently processed is referenced on the hash table **803** having the exemplary data configuration illustrated in FIG. **15**. Then, it is determined whether or not the value of the user type item indicates "priority" (in step S**1601**).

If the value of the user type item does not indicate "priority" and indicates "general" (the user ID illustrated in FIG. **15** is not 0, for example) or the answer to the determination of step S**1601** is NO, a server thread **106** is not activated in the same manner as the flowchart of FIG. **9**.

If the value of the user type item indicates "priority" (the user ID illustrated in FIG. **15** is 0 or indicates a root user or the like) or the answer to the determination of step S**1601** is YES, the process returns to step S**904** and a server thread **106** may be assigned. However, if the number of executed threads for all the users reaches the number, held by the variable Ta, of times of concurrently executable access or the answer to the determination of step S**904** is NO, the same control process as the flowchart of FIG. **9** is executed and the assignment of a server thread **106** to the prioritized user is suppressed.

As described above, in the control operation according to the second embodiment, a failure of a process performed by the prioritized user such as the system administrator may be inhibited by the process of controlling the number of threads executed to access the disk device **120**.

The thread assignment controller **102** described with reference to FIG. **8** does not use the round-robin method in order to assign the threads and may control, based on the amounts (hereinafter referred to as IO amounts) of data subjected to file access in the past, the assignment of threads to users while prioritizing a user whose IO amount is small over a user whose ID amount is large. The execution of the control may reduce the probability of the occurrence of a delay, caused by access performed by the user whose IO amount is large, of access performed by the user whose IO amount is small.

Specifically, in the process of suppressing an upper limit on the number of executed threads for each user, the control may be executed without the round-robin method so as to ensure that a thread is assigned to a user whose past IO amount is smallest. However, the IO amounts may be periodically cleared in order to avoid a state in which a thread is not assigned to a user whose IO amount was temporarily large in the past.

FIG. **17** is a diagram illustrating an exemplary data configuration of a hash table **1701** stored on the memory of the server machine **100** by the thread assignment controller **102** as the third embodiment in which an operation of executing the control based on the IO amounts is achieved. The hash table **1701** is formed by adding an IO amount item (highlighted in gray) to the aforementioned hash table **803** illustrated in FIG. **8**. Values of the IO amount item may be set on a bite basis.

FIG. **18** is a flowchart of an example of a process of assigning a thread according to a third embodiment in which an operation of executing the aforementioned control based on the IO amounts is achieved. In FIG. **18**, steps of executing the same processes as the flowchart of FIG. **9** are represented by the same reference numbers as the flowchart of FIG. **9**. Differences between the process depicted in the flowchart of FIG. **18** and the process depicted in the flowchart of FIG. **9** are steps S**902**', S**907**', S**910**' with which steps S**902**, S**907**, and S**910** illustrated in FIG. **9** are replaced.

In step S**902** illustrated in FIG. **9**, a request within any of the request queues **704** (**704**A, **704**B, . . .) (exemplified in

FIG. **7**) generated for the users by the request receiver **101** and stored on the memory is referenced according to the round-robin method, for example. On the other hand, in step **S902'** illustrated in FIG. **18**, a request within a request queue **704** for a user ID corresponding to an IO amount item representing the smallest IO amount is referenced in the hash table **1701** having the exemplary data configuration illustrated in FIG. **17**.

In step **S907'** illustrated in FIG. **18**, the process of step **S907** illustrated in FIG. **9** and the following process are executed. In the hash table **1701** having the exemplary data configuration illustrated in FIG. **17**, an IO amount of current disk access is added to a value of an IO amount item corresponding to a user ID for which the disk access process is executed.

In step **S910'** illustrated in FIG. **18**, the process of step **S910** illustrated in FIG. **9** is executed and values of IO amount items of all records for all user IDs in the hash table **1701** having the exemplary data configuration illustrated in FIG. **17** are cleared. This avoids a state in which a thread is not assigned to a user whose IO amount was temporarily large in the past.

FIG. **19** is a diagram illustrating an example of a hardware configuration of the server machine **100** that achieves the distributed file system provided with the functions illustrated in FIG. **1** as a software process.

A computer illustrated in FIG. **19** includes at least one CPU **1901**, a memory **1902**, an input device **1903**, an output device **1904**, an external storage device **1905**, a portable storage medium driving device **1906**, and a communication interface **1907**, which are connected to each other by a bus **1908**. A portable storage medium **1909** is inserted into the portable storage medium driving device **1906**. The configuration illustrated in FIG. **19** is an example of the server machine **100** that achieves the distributed file system illustrated in FIG. **1**. The computer is not limited to this configuration.

The CPU **1901** controls the overall server machine **100**. The memory **1902** is a RAM or the like and temporarily stores a program and data upon the execution of the program, the update of the data, or the like, while the program and the data are stored in the external storage device **1905** (or the portable storage medium **1909**). As the data, the hash tables illustrated in FIGS. **3**, **7**, **8**, **15**, and **17**, the request queues, the aggregation table **1** illustrated in FIG. **10**, the aggregation table **2** illustrated in FIGS. **13**A to **13**C, and the like are stored in the memory **1902**. The CPU **1901** reads the program into the memory **1902**, executes the program, and thereby controls the overall the server machine **100**.

The input device **1903** detects an input operation performed by a user through a keyboard, a mouse, or the like and notifies the CPU **1901** of a result of the detection.

The output device **1904** outputs data transmitted under control of the CPU **1901** to a display device or a printing device.

The external storage device **1905** is, for example, a hard disk storage device. The external storage device **1905** is used mainly to store various types of data and the program.

The portable storage medium driving device **1906** stores the portable storage medium **1909** such as an optical disc, an SD card, or a CompactFlash (registered trademark) card and plays an auxiliary role for the external storage device **1905**.

The communication interface **1907** is a device configured to connect the server machine **100** to a communication line such as a local area network (LAN) or a wide area network (WAN).

The system according to the present embodiment is achieved by causing the CPU **1901** to execute a process program having the functions achieved by the processes depicted in the flowcharts of FIGS. **9**, **11**, **12**, **14**, **16**, and **18** and the like. The program may be stored in the external storage device **1905** or the portable storage medium **1909** and distributed or acquired from the network **130** (illustrated in FIG. **1**) connected to the communication interface **1907**.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. An information processing device, comprising:

a memory; and

one or more central processing units coupled to the memory and configured to:

control accesses to a device based on requests from users,

record a start time of each access to the device and an end time of each access to the device,

determine a load state of the device based on an elapsed time period from a start time to an end time, and

limit, based on the load state of the device, a number of threads for each one of the users, the threads being concurrently executable programs to access the device based on access requests to the device from each one of the users.

2. The information processing device according to claim **1**,

wherein the one or more central processing units are configured to divide a data size of the requests from the users into a certain size causing an elapsed time period for each access to the device to be within a certain elapsed time period and of executing each access to the device,

wherein the one or more central processing units are configured to count, for each access, a number of times of the accesses, executed in concurrent, to the device for each of certain time periods within the elapsed time period for each access and to calculate, for each access, a number of times of accesses executed concurrently within the elapsed time period for each access from a result of counting the number of times of accesses for each of the certain time periods,

wherein the determination is to aggregate elapsed time periods for numbers of times of accesses executed concurrently using the number of times of accesses executed concurrently within an elapsed time period for each access and calculate, based on a result of aggregation, number of times of concurrently executable accesses, suppressing a delay of each access to the device, of times of accesses executed concurrently, and

wherein the control is to limit the number of the threads that are concurrently executable programs to access the device based on the requests from each one of the users so as to ensure that the limited number of the threads does not exceed number of times of concurrently executable accesses for each one of the users.

3. The information processing device according to claim 2,

wherein the certain size divided from the data size of the requests, is each equal to a block size of a file system of the device.

4. The information processing device according to claim 2, wherein when an elapsed time period corresponding to a number of times of accesses executed concurrently is not calculated from records of elapsed time periods for accesses and records of numbers of the times of accesses executed concurrently, the determination is to calculate the elapsed time periods corresponding to a number of times of accesses executed concurrently by executing interpolation based on records of the elapsed time periods for accesses using size the certain sizes and records of numbers of the times of the accesses executed concurrently.

5. The information processing device according to claim 2,

wherein the control is to count a number of concurrently executed threads for each one of the users and number of concurrently executed threads for the users, process the requests from the users so as not to cause the counted number of the concurrently executed threads for the users to exceed a number of times of concurrently executable accesses, and reduce, based on a user for which the counted number of threads is smallest among counted numbers of concurrently executed threads for the users, a number of threads that are concurrently executed to access the device based on a request from another user when the request from the another user causes the counted number of concurrently executed threads for the users to exceed a number of concurrently executable accesses.

6. The information processing device according to claim 5,

wherein the control is to assign, to a prioritized user on a priority basis, a number of threads that are concurrently executed to access the device based on a request for the prioritized user.

7. The information processing device according to claim 5,

wherein the control is to assign, on a priority basis to a user who has accessed, in the past, data of which an amount is smaller than amounts of data accessed by each of other users in the past, a number of threads that are concurrently executed to access the device based on requests for the user.

8. A non-transitory, computer-readable recording medium having stored therein a program for causing a computer to execute a process, the process comprising:

recording, in an information processing device configured to control accesses to a device based on requests from users, a start time of each access to the device and an end time of each access to the device;

determining a load state of the device based on an elapsed time period from a start time of each access to an end time of each access; and

limiting, based on the load state of the device, a number of threads for each one of the users, the threads being concurrently executable programs to access the device based on access requests to the device from the each one of the users.

9. A method for controlling an information processing device and causing computer to execute:

recording, in the information processing device configured to control accesses to a device based on requests from users, a start time of each access to the device and an end time of each access to the device;

determining a load state of the device based on an elapsed time period from a start time to an end time; and

limiting, based on the load state of the device, a number of threads for each one of the users, the threads being concurrently executable programs to access the device based on access requests to the device from each one of the users.

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